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I. OBSERVATIONS ON EGREGIA MENZIESII.

Francis Ramaley.

Introduction.

Egregia menziesii is one of the largest and most conspicuous of the marine plants occurring on the shores of Vancouver Island. Its great abundance makes it a favorable object of study. It is easily collected at times of extreme low water when it is found in the zone with *Alaria* and *Laminaria*. A morphological study of the plant was made in the field and in the laboratory of the Minnesota Seaside Station. This study has since been carried on with preserved material. The author desires to thank Professor Conway MacMillan for suggesting to him the subject for study and for aid during the progress of the work. He is also under obligation to Miss Josephine F. Tilden for helpful suggestions.

This plant was first described by Turner [1] as *Fucus menziesii*. It was afterwards referred to the genus *Macrocystis* by C. A. Agardh [2] and was later called *Phyllospora menziesii* by the same author.[3] In 1876 Areschoug [4] made it the type of a new genus, *Egregia*. Descriptions of the plant or records of its collection have been given in numerous works besides those mentioned above.[5]

The present writer has not had access to Turner's work but that author's description and figure are copied by later writers.

Distribution.

The plant has been collected at various points along the northwest coast of America, first by Menzies, who obtained it as far north as Nootka Sound, later by botanists of the Beechey voyage [6] and by Dr. Lyall and C. Wood at Esquimalt and Fuca Strait.[7] In later years collections have been made by Dr. Eisen, Dr. Anderson, Dr. Howe, Professor Saunders, Dr. Setchell, Miss Tilden and others in California, Washington and British Columbia. According to Professor Setchell [8] *Egregia menziesii*

extends to Port Harford some distance south of San Francisco. Below this point it is replaced by *Egregia lævigata* Setchell with its numerous forms. The exact northern limit of distribution is not known.

EXTERNAL MORPHOLOGY.

The young plant consists of hold-fast (root area) and frond (shoot area), the latter consisting of a short stipe and a well-developed lamina (*Plate II.*). The growing point is situated at the base of the lamina. In early life the plant has much the appearance of a young *Laminaria* or *Alaria*. The stipe soon branches in the merismatic region, each branch becoming differentiated into stipe portion (rachis) and lamina. Both rachis and lamina increase in length but the lamina commonly attains a length of only 3 to 5 dm., while the rachis may become very long. Some plants collected in the month of July were 6 to 8 meters in length. The lamina grows but very little after the rachis has attained a length of one meter.

The mature plant may have from ten to forty long branches and be of great size (*Plate I.*). The branched basal part of the frond resembles the basal part of *Lessonia*. At the sides of the rachis and lamina of each branch there are rows of closely packed leaf-like proliferations of various shapes. Plants of the related genus *Alaria* also have phylloid outgrowths but they are entirely confined to the stipe, never appearing on the lamina.

The holdfast. — In large plants this is a convex disc about 1 dm. in diameter, rather smooth on the attached surface, while the upper surface consists of dichotomously much-branched, overlapping, nearly cylindrical blunt fibers about 5 mm. in diameter, smooth and of a light brown color.

The stipe. — At the point of union with the holdfast the stipe is nearly terete but the first branches are given off within a distance of 2 or 3 cm. and from that point they are all somewhat flattened-cylindrical in shape, becoming at a little distance strap-shaped. This flattened strap shape is maintained the entire length of the rachis of each branch. Branching does not occur at any great distance from the holdfast. The rachis is dark brown in color, distinctly roughened with tuberculate and short ridge-like thickenings.

The lamina is of a somewhat lighter color than the rachis, is generally 25 to 35 mm. in width and about twelve times as

long as wide. It is slightly narrowed both at base and apex. The lamina is longitudinally plicate with short wrinkles and linear thickenings. Since the plants are exposed to the beating of the surf portions of the lamina or even the entire lamina with a part of the rachis frequently become torn away.

Proliferations. — These occur on both rachis and lamina and arise as outgrowths of the merismatic area. These are the "leaves" or "laminæ" of authors. About four different kinds of proliferations may be distinguished. These are the ordinary spatulate or ovate or cuneate form, the branched laciniate form, the vesicle-bearing forms and the short cuneate gonidia-bearing form. (*Plate III., Figs. 1–27.*)

These short cuneate proliferations occur all along the margins of the rachis of old fronds scattered among the longer proliferations. In July not very many of the plants were actually producing gonidia, although these proliferations were present. Whether all of these are capable at some time of producing gonidangia is not known.

Areschoug speaks of "capillary" proliferations. These are probably the branched laciniate kind which in drying become much shrunken and could easily be called "capillary." The same author, who is followed by De Toni, describes the gonidiophylls as jugate. This is certainly not the case in fresh material. Kjellman [5] says that there are certain proliferations, like the usual spatulate form, except that they are irregularly ribbed, and that they bear the sporangia. This statement is quite incorrect. The gonidiophylls are always short, only 1 or 2 cm. long, while the ordinary proliferations are three or four times as long. Besides this they are not ribbed at all.

The proliferations of the lamina are always shorter than those of the stipe and air vesicles and gonidiophylls are never present on the lamina. The longest proliferations of any given branch occur near the region of growth between rachis and lamina, *i. e.*, as the branch becomes older it produces longer outgrowths. The longest proliferations of the lamina are usually from 4 to 6 cm. in length while those of the stipe are 9 to 12 cm. The branched proliferations are more abundant on the lamina than on the stipe.

Air vesicles, as indicated above, occur on the rachis, never on the lamina. They are the swollen and lengthened stalks of

otherwise ordinary proliferations and so are surmounted by spatulate or ovate-cuneate or branched leaf-like blades unless these be broken. The blades of these vesicle-bearing proliferations are often branched when those of neighboring proliferations are of the common form. The vesicles when fully grown are obovoidal or ellipsoidal, mostly 2.5 to 3.5 cm. in length. In the older parts of the rachis, as first described by Ruprecht, they are more bulged out, becoming nearly spherical and hence somewhat shorter. In the old vesicles the surmounting blade has always disappeared.

Comparison with other Laminariaceæ.

The morphology of the plant was not understood by early writers because of the fragmentary material studied. Turner and Agardh seem to have had only small portions of the stipe with no part of the lamina. Ruprecht apparently had good material. His *Plate IV.* is accurately drawn and shows both rachis and lamina. He, however, overlooked the branched laciniate proliferations; at any rate he does not show them in the drawing. Areschoug and De Toni seem to have neglected the work of Ruprecht. They do not mention the laminæ of the branches and so fail to show the morphological similarity of this plant with other Laminariaceæ. Professor Setchell[9] first pointed out the fact that *Egregia* conforms to the *Alaria* type in its morphology. It should be noted, however, that the plant body of *Egregia* shows a much higher degree of differentiation in the branching of the stipe and the character of the proliferations. In *Alaria* the proliferations occur only on the stipe. They are known as gonidiophylls. In *Egregia* only one kind of proliferations, the short somewhat cuneate form, bears gonidia. The others, both of the rachis and lamina, are sterile and should not be spoken of as gonidiophylls.

Egregia consists, as the other Laminariaceæ do, of holdfast, stipe and lamina, but the branching of the stipe gives rise to members (branches) each having the general characteristics of the entire frond in *Alaria*. The multiform proliferations largely replace functionally the lamina, which is here greatly reduced in size and importance. Because of the great elongation of the stipe a floating apparatus has become necessary and this is provided in the vesicles developed by the swelling of the stalks of certain proliferations.

Anatomy.

It will not be necessary to discuss at length the structure of other plants in the family Laminariaceæ. A rather full bibliography may be found in the recent articles by Professor MacMillan on *Nereocystis*[10] and *Lessonia*.[11]

It may be remarked that no special structural features were noted in *Egregia* which do not occur in other Laminariaceæ. Following Wille [12] the term trumpet hyphæ is used as synonymous with sieve tube, for Wille pointed out that the sieve tubes are merely old trumpet hyphæ. In *Egregia* there is no special sieve tube area at the periphery of the pith web such as has been described in other genera. There were no mucilage canals and no cryptostomata were seen.

At the present time only a somewhat general account will be given of the anatomy of *Egregia*. A more complete discussion of details of the anatomy and particularly the cytology will be given in a future paper.

Methods. — Material was hardened in chromic acid solution. The paraffin method of embedding was used and sections from 5 microns to 10 microns in thickness were cut. Staining on the slide was found most satisfactory, although some material was also stained in bulk. The sections were mounted from xylene into Canada balsam. By far the most useful double staining for general anatomical work was done with hæmatoxylin and Bismarck brown. Flemming's triple stain is also good.

Holdfast. — Each branch of the holdfast shows, on examination, an external cambium of thin-walled parenchymatous elements. An ill-defined cortex consists of three or four layers of cells similar to those of the epidermis. All these cells may contain an abundance of granular carbohydrate material. The pith comprising the chief part of the structure consists of more elongated cells, but with walls likewise thin. There is no mucilaginous thickening, nor are there well-developed trumpet hyphæ as in the pith of other parts of the plant.

Main stipe. — This is a short cylindrical structure, the branches of which form the rachides bearing the proliferations. The outermost ten or twelve layers of cells are thin-walled and merismatic. Next comes the cortical region in which the cells are prosenchymatous and have somewhat thick-

ened walls. The central part of the main stipe is a pith web consisting of more or less interlacing hyphæ, showing mucilaginous thickening of the walls. It is much the same as the pith web of the rachis and lamina.

Rachis.—This is a strap-like structure, rough-tuberculate on both surfaces. The elevations are to be considered as emergences consisting of cortical and hypodermal cells covered with epidermis. About one third of the entire thickness of the rachis is embraced in the pith web (*Fig. 28*). The epidermis consists of thin-walled prismatic cells with slightly thickened outer wall. Chlorophyll bodies are present here and in the hypoderma; the cells of the latter tissue resemble those of the epidermis in appearance (*Fig. 29*). There is a gradual transition to the cortex where the cells are thicker walled and elongated in the direction of the long axis of the rachis. Here chlorophyll bodies are absent. A somewhat well-marked limit is seen between cortex and pith web. The gelatinous thickening of the cell walls of the inner cortex gives an appearance of collenchyma (*Fig. 30*) when seen in cross section. A much greater development of gelatinous material occurs in the pith web (*Fig. 31*). In this region most of the hyphæ extend longitudinally, but there are many also passing horizontally and about as many in the direction of the thickness of the strap. Thus a section of the pith web, cut in any plane, will show the hyphæ extending in various directions; some may be followed for a distance, others are cut straight across and some obliquely.

Lamina.—This is very much roughened externally (*Plate II.*); numerous short plications extend longitudinally and also in part obliquely. The pith web is elevated at these places (*Fig. 32*), so that the emergences are deep-seated and not merely cortical as in the rachis. There are no other structural differences between lamina and rachis; epidermis, hypoderma, cortex and pith are essentially similar in the two regions. There is no real pith web in the proliferations, but the cells of the medullary region often show a certain amount of thickening (*Fig. 33*). The cells of the epidermis are generally short, but in some cases rather tall prismatic, just as in the main rachis and lamina. The tall prismatic cells are found regularly in the epidermis of young air vesicles (*Fig. 34*). The cells of the epidermis and hypoderma are frequently well filled with granular reserve carbohydrates. No important differences

were observed between the structure of the proliferations of the stipe and of the lamina. The gonidia-bearing proliferations bear gonidangia over the whole surface on both sides and on the edges. A small part of the broad blunt distal end is sterile. The gonidangia and paraphyses have the usual structure for members of the family as described by various observers.

Meristem. — The merismatic region between the rachis and lamina shows in its structure the same areas recognized in the older parts. The cell cavities of the pith web are rather large and become smaller with the mucilaginous thickening of the walls. All the cells of the merismatic area are quite thin-walled.

Summary and conclusions. — The morphology of *Egregia* is best understood if we consider it as an *Alaria* in which the stipe is branched close to the holdfast and each branch has taken on the characters of the entire shoot area of *Alaria*. Instead, however, of a few large proliferations of one kind borne on the stipe, *Egregia* has hundreds or thousands of small proliferations on both rachis and lamina. These proliferations are of various shapes. The stalks of some are swollen and hollow, forming air vesicles. These occur only on the rachis, never on the lamina. The gonidia-bearing proliferations are always small and rather cuneate in outline. Like the vesicles they are confined to the rachis. The laminæ are narrow and comparatively short, so the photosynthetic function develops chiefly on the proliferations. It is properly to display these that the development of vesicles has been necessary.

Egregia agrees rather closely with other Laminariaceæ in its anatomy. The stipe, rachis and lamina all show the usual areas, epidermal, hypodermal, cortical and medullary. The thickenings of the rachis and lamina are irregular multicellular emergences which in the lamina are above thickened places of the medulla (pith web), but which in the rachis are more superficial, consisting only of thickened areas of the other layers. The pith web is present in the main stipe but not in the branches of the holdfast. There is either no pith web in the proliferations or it is poorly developed. All of the proliferations have the same anatomical characters. An abundance of carbohydrate reserve material is usually present in the outer cells of the proliferations and also of other parts of the plant. In the structure of the gonidangia *Egregia* agrees with other

Laminariaceæ. Mucilage canals do not occur. No cryptostomata were seen.

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Explanation of Plates.

Plate I. The beach at low tide, Vancouver Island, at Minnesota Seaside Station. A large plant of *Egregia* is near the foreground; just back of it is placed a hat for comparison as to size. The plant is seen to consist in great part of very long strap-shaped branches with thousands of small proliferations along the sides. The plants in the foreground at the left are species of *Alaria*, those near the edge of the water in the background are *Lessonia*. Photographed by Hibbard.

Plate II. Photographs of young *Egregia* plants showing well the differences between rachis and lamina. Numerous vesicles may be seen on the rachis. These are the swollen bases of otherwise ordinary proliferations. Many of the proliferations of the lamina have been torn off. This is a common occurrence. These figures are about one half natural size. Photographed by Hibbard.

Plate III. 1–10. Proliferations of the lamina. 1–5. Common forms. 6, 7, 8. Forms occasionally met with. 9, 10. Forms somewhat numerous on old fronds. 11–27. Proliferations of the stipe. 11–17. Very common forms; those with vesicles (13–17) are not otherwise

different from 11 and 12. 18–26. Branched proliferations, some with, some without vesicles; the former are more often branched; thus 26 is more common than 25. 27. Group of gonidia-bearing proliferations, the part above the dotted line in each is sterile. All these figures were drawn from fresh material and are one half natural size.

Plate IV. 28–34. Drawings illustrating anatomical structure. 28. Diagram of a vertical section of the rachis, × 16; the emergences are seen to consist only of outer tissues, the pith web is about one third of the entire thickness of the rachis. 29. Longitudinal vertical section of the epidermis and the hypodermal region of the rachis from a section 5 microns thick; the outer walls of the epidermis are somewhat thickened, × 500. 30. Cross section through the inner cortex of the rachis, the thickened walls give the tissue the appearance of collenchyma, × 500. 31. Drawing of a portion of the pith web of the rachis. Some trumpet hyphæ are seen. The hyphæ extend in every direction and are cut in different ways. All the cells have gelatinous thickening of the walls, so that they appear as if in a gelatinous matrix, × 500. 32. Diagram of a vertical section of the lamina showing the thickening of the pith web below the emergences, × 16. 33. Cross section of a proliferation of the lamina; it will be seen that the cells in the middle of the structure are somewhat thick-walled. The epidermis here is composed of short prismatic cells, × 170. 34. Cross section of the wall of a small air vesicle. The epidermal cells are tall and prismatic in shape, the cells next the air cavity are somewhat thick-walled and rather flat; in older vesicles the epidermal cells are more flat, × 170.

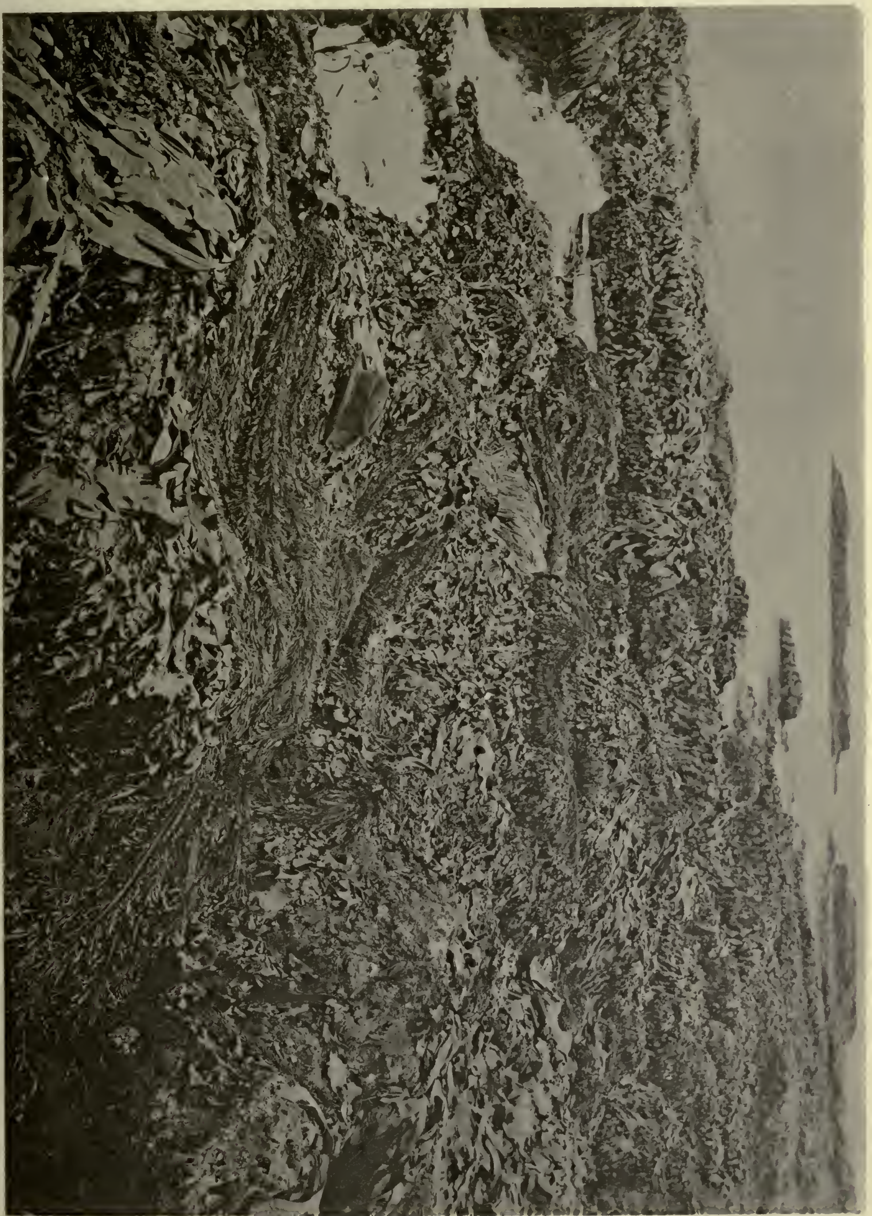

PLATE I.

HELIOTYPE CO., BOSTON.

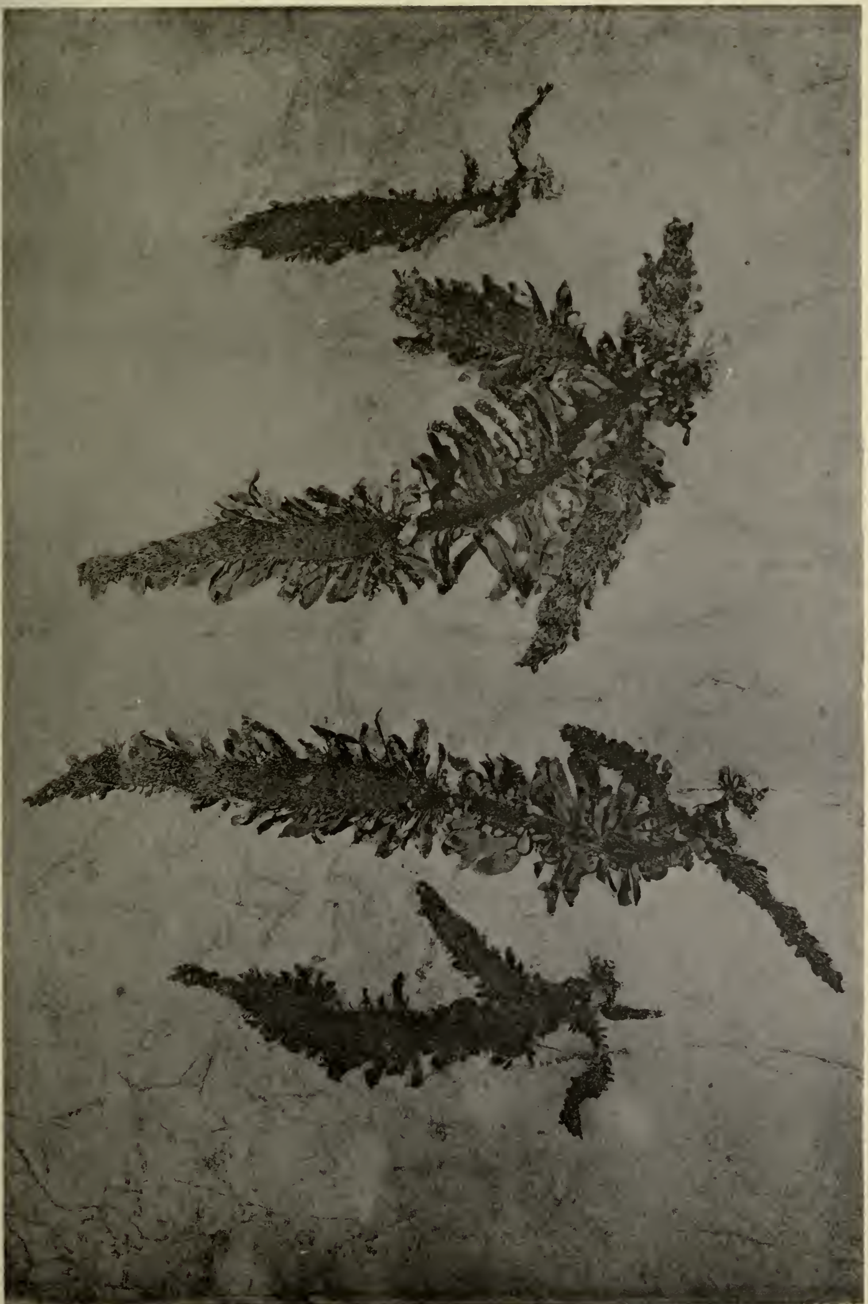

PLATE II.

HELIOTYPE CO., BOSTON.

PLATE III.

HELIOTYPE CO., BOSTON.

II. OBSERVATIONS ON TRICHOGLŒA LUBRICA.

FRED. K. BUTTERS.

The specimens of *Trichoglœa lubrica* (Harv.) J. Ag., upon which the following observations were made, were collected by Miss Josephine E. Tilden, June 13, 1900, at Kahuku point, at the northwest extremity of the island of Oahu, Hawaiian Islands, from material which had been cast up on the beach. Specimens from the same collection were subsequently distributed by the collector (American Algæ, Century V., No. 419) as *Nemalion ramolusum* Harv.

Several entire plants were preserved in a 1 per cent. solution of formaldehyde, and a small amount of material was killed in 1 per cent. chromic acid, and then, after thoroughly washing, transferred to 70 per cent. alcohol in which it was preserved. Material treated according to both of these methods was used in preparing the present paper. For most purposes the formaldehyde material proved more useful, as by this method the gelatinous matrix of the frond was preserved more nearly in its natural condition. In studying the microscopic anatomy it was found that many points could be best made out by picking to pieces portions of the frond with needles, or by crushing portions under the cover glass. The latter process was aided by the gelatinous nature of the frond. Besides preparations made by dissecting and crushing the frond, sections were made by various methods. For the study of the anatomy of the vegetative tract it was found that the best preparations were obtained by imbedding the material in celloidin, hardening the block with chloroform vapor, and cutting in the usual manner upon the sliding microtome. Sections were thus obtained in which the loose cortical structures were held in their proper positions. Useful preparations were made by mounting the material on a freezing chamber in a drop of gum arabic solution and cutting the frozen mass on the sliding microtome. This material did

not retain the cortical structures in place, but gave excellent results in the dense medullary region. Preparations were made also by imbedding the material in paraffin, and sectioning in the usual manner. By this means sections 6.66 microns in thickness were obtained. They were of little value in studying the vegetative tract, on account of the loose nature of the tissues involved, and the great shrinkage of the gelatinous matrix incident to this process, but they gave excellent preparations for the study of the later stages in the development of the cystocarp.

Gross Anatomy. — In the most perfect specimens the frond is vermiform and much branched (*Fig. 1*). About six main branches arise from a small disc-shaped holdfast. These main branches are repeatedly branched, pinnately and also dichotomously, and the ultimate branches are often furcate a short distance from the tip. The extreme length from the holdfast to the tip of the longest branch is 20 cm., the average height of the frond about 15 cm. The branches are 1–3 mm. in diameter, almost cylindrical, tapering gradually to about .5 mm. in diameter at the obtuse tip. The branches are very mobile and yield freely to the slightest motion of the water.

The whole thallus is gelatinous, and all parts of it, except the youngest growing portions of the branches, contain a considerable quantity of calcium carbonate which forms a white granular sheath about the medullary portion of each branch, and is itself surrounded by the outer cortical portion. According to the collector the color of the fresh frond was brownish-red, but all trace of color had disappeared in the preserved material.

Minute Structure of the Vegetative Tract. — The frond consists of two areas, a medullary portion and a cortical layer (*Plate V., Fig. 6*). Throughout the frond the filamentous structure of the tissues which is common among the Rhodophyceæ may be clearly distinguished. The filaments of cells lie imbedded in a general thin gelatinous matrix which is formed by the coalescence of the swollen gelatinous outer covering of the cells.

The medullary region consists of intermingled longitudinal filaments of two distinct types (*Figs. 6, 7*). The larger filaments are the primary filaments of the frond, and all other parts are derived from their lateral branching. They are composed of cells 120–1,300 mic. long and 12–120 mic. wide.

These cells are widest in their median portion, and are usually constricted at the ends. In the older portion of the frond they becomes highly vacuolate and finally almost devoid of contents, so that only the cell wall is capable of taking any appreciable stain.

Filaments of this type are occasionally unbranched for a considerable distance, but usually each filament gives rise to a series of lateral branches, of which one arises near the upper end of each cell of the filament. Occasionally, one of these lateral branches runs parallel to the parent filament to which it is in all respects similar, and so forms an additional medullary filament, but in most cases the lateral branch passes out perpendicularly into the peripheral region of the frond, and gives rise to a branch system of cortical filaments (*Figs. 3, 5*). In mature portions of the frond the primary filaments are often crowded together in the outer medullary region, forming a rather irregular hollow cylinder, within which are other more widely scattered primary filaments (*Fig. 6*).

Besides these larger filaments there are smaller filaments which run irregularly among the larger filaments (*Fig. 7*). These smaller filaments are composed of cells 45–140 mic. long, and 4–10 mic. in diameter, and the filaments are of nearly uniform diameter throughout, in which respect they differ from the larger filaments as well as in size. Their protoplasmic contents are more dense than those of the larger filaments.

These smaller filaments branch sparingly. They arise by the secondary branching of the cortical filaments, as will be described in detail in connection with the structure of the cortical portion of the frond.

The cortical area of the mature frond is composed of a complex branch system of filaments (*Figs. 4, 5*), and may be divided approximately into two regions, an outer or assimilating area, which forms the surface of the frond and consists of comparatively simple moniliform filaments, and an inner area which lies between the medulla and the assimilating area, and consists of intricately interwoven filaments of complex branching habit.

To appreciate the structure of the cortical area, its development must be understood. Examination of the growing point of the frond shows the dense medullary region, which here consists entirely of the large primary filaments, and surround-

ing this a cortex composed of almost unbranched filaments which run outwards from the medulla. At the extreme apex of the frond these cortical filaments are almost cylindrical throughout. Each one has a conical apical cell, and is evidently in active growth. A very short distance from the apex of the frond the distal cells of each filament are seen to have become nearly spherical, giving that portion of the filament a moniliform aspect, and thus the assimilating area is established. Apparently after the distal cells of a filament become thus matured it undergoes no further growth by cell division, but the proximal cells may increase very considerably in length. Soon secondary cortical filaments appear in the inner cortical region, arising by the proliferation of the primary cortical filaments. A secondary filament generally arises as a lateral outgrowth from the distal end of one of the cells of a primary filament. In all respects, except their origin, these secondary filaments exactly resemble the primary ones. They grow out among the latter for a time, and eventually mature, thus increasing the number of assimilating filaments. The secondary filaments may in turn give rise by proliferation to other similar filaments. Branching of the cortical filaments has already commenced in the lower part of the tip shown in *Fig. 2*. A few millimeters farther from the tip, branching will have gone much farther, and each of the original cortical filaments will have developed into a complicated branch system, as in *Fig. 3*, which shows two cells of a primary medullary filament, each of which bears a system of cortical filaments which has developed by the secondary branching of one simple cortical filament.

At about this stage in the growth of the frond, another kind of filament makes its appearance. Lateral outgrowths arise from the cells of the inner cortex, usually from their proximal portions (*S*, *Figs. 3*, *5*). These outgrowths develop into cylindrical, almost simple filaments of much smaller diameter than the cortical filaments. The first of these filaments to appear in any cortical branch system is generally formed as an outgrowth from the proximal part of the basal cell of the system. These filaments are produced successively from the cells throughout the inner cortical region, and eventually the same cortical cell may give rise to several of them. They take an irregular course towards the medullary part of the frond, and eventually grow in among the large medullary filaments,

forming the smaller filaments of the medulla. Their general course after reaching the medullary region is approximately longitudinal and usually towards the base of the frond, but they sometimes turn upward toward the growing point, and a cross-section of the frond often shows them running in various oblique directions among the primary filaments (*Fig. 7*).

The production of the secondary cortical filaments and of these smaller medullary filaments continues for a long time, so that the branch systems become finally very intricate (*Fig. 4*). Even in the older parts of the frond immature cortical filaments may frequently be found among those which have long been mature (*Fig. 14*). In the mature frond there are somewhat large spaces among the cortical cells close to the medulla, and it is in these spaces that the calcium carbonate is deposited which incrusts the medullary region of the frond (*Fig. 6*).

In mature parts of the frond the diameter of the principal filaments of the inner cortical region is greatest close to their origin from the medullary filaments. The cells here average 65 x 12 mic. Farther from the medulla the cells are often longer, but more slender. Still farther out the cells are again shorter and wider, and pass by a gradual transition into the almost spherical cells of the assimilating area.

The outer cortical assimilating area of the frond consists of moniliform filaments, simple or somewhat sparingly branched in their proximal portions. In the region of transition from the inner cortex, the cells are somewhat elliptical, with an average size of 24 x 12 mic. In the distal parts of the filaments the cells are slightly wider and much shorter, so that they are almost spherical or often a little flattened, averaging about 14 x 15 mic. The terminal cell of a mature filament is usually somewhat smaller than the cells immediately proximal to it. In the maturation of a filament one or more of the distal cells frequently fail to round up, and finally break down, leaving the filament capped by a loose floating mass of material resulting from their deliquescence (*Fig. 14*).

The general structure of the frond is thus seen to agree closely with that which has been described in the nearly related genus *Liagora* (Agardh, J. G., Analecta Algologica, III., 96. 1896) and especially with that of the subgenus *Euliagora* (*l. c.*, p. 97). Agardh describes the structure of *Liagora viscida* (Forsk) J. Ag. as typical of this subgenus. He notes the two

kinds of medullary filaments, and says further, in describing the smaller filaments: "In partibus adhuc junioribus frondis sunt haec fila tenuiora longitudinalia, a quibus fila strati corticalis exeuntia observare, credidi." Specimens of a species of *Liagora* belonging to this subgenus, and probably *Liagora leprosa* (Tilden, Josephine E., American Algæ, Century V., 417), have been examined in connection with the preparation of the present article, and in them the origin of the smaller medullary filaments was found to be identical with that in *Trichoglœa lubrica*. It is easy to see how the mutual relationship of the cortical and the smaller medullary filaments might be misunderstood, and it is suggested that further observations may show the smaller medullary filaments to be of cortical origin in the other species of *Liagora*, also.

Cytology of the vegetative tract.—In material stained with acid fuchsin, or with anilin-water-safranin the nuclei appear as nearly spherical densely staining bodies. With the exception of the cells of the larger medullary filaments, in which no satisfactory nuclear stains were obtained, each cell contains a single centrally located nucleus. The nuclei of the outer cortical cells are 2–5 mic. in diameter, those of the other parts of the frond generally somewhat smaller. None of the material was preserved with intention to show division stages of the nuclei.

Surrounding the nucleus and lying close to the outside of the cell is the chromatophore. This body is irregularly ring-shaped, with processes running inward towards the nucleus. In the spherical cells of the outer cortex the chromatophore almost fills the cell, but in the more elongated cells of the inner cortex, it forms a comparatively narrow band about the center of each cell. As it stains heavily with acid fuchsin, it often entirely conceals the nucleus, so that, especially in the outer cortex, the nuclei can be studied to advantage only in sectional material. In the vicinity of the chromatophore there is often a deposit of floridean starch. This is most abundant in the special photosynthetic cells, but is found also in other cells which contain a chromatophore. The cells of the smaller medullary filaments resemble those of the cortical filaments except in shape. They have a very narrow chromatophore. The cells of the large medullary filaments have no chromatophore and no distinctly staining nucleus was seen in them.

Throughout the frond the cytoplasmic strands between the adjacent cells of a filament are evident. In some cases these may be seen in unstained material, and in preparations stained with a solution of iodine in water and potassium iodide they are easily visible in all parts of the plant.

With iodine-potassium-iodide solution and sulphuric acid the cell walls give a faint cellulose reaction, stronger in the medullary region than in the cortex. In the cells of the medulla and inner cortex, in preparations stained with acid fuchsin, a ring of more densely staining cell wall is seen between adjacent cells, surrounding the protoplasmic connection between the cells. This ring does not display the cellulose reaction with iodine and sulphuric acid and is not stained with the chlor-zinc-iodide callus reagent.

Several reagents, such as gentian-violet and bismarck-brown, stained the gelatinous matrix of the frond. In some sections, stained with bismarck-brown, it was possible to make out the structure of the matrix, a definite portion of it being seen as a sheath surrounding each of the cortical filaments.

The reproductive tract.—Both antheridia and procarps were found upon the plants which were examined. There is often a localization of these organs, so that an entire branch of the frond may be male or female, but more often both kinds of reproductive organs are produced close together upon the same branch of the frond and often upon adjacent groups of cortical filaments springing from the same medullary filament, but apparently never upon the same branch system of cortical filaments.

The antheridia.—Antheridia arise by the proliferation of the distal cells of a peripheral filament (*Figs. 5, 8*). The distal cells in this case average 9 x 6 mic., being smaller than the immediately proximal sterile cells and smaller than the distal cells of mature sterile filaments. They are devoid of floridean starch, while the immediately proximal sterile cells are filled with it. These central cells of the antheridial branch bear numerous simple or branched chains of almost spherical, somewhat thick-walled cells about 2.8 mic. in diameter. The terminal cells of these chains are the sperm mother cells and when they are mature each one discharges its sperm from the enclosing cell wall. The sperms are the usual spherical non-motile sperms of the Florideæ.

The procarp and cystocarp.—Procarps are borne terminally on cortical filaments having the aspect of the ordinary immature filaments of that area. They were never found produced by the primary cortical filaments of the growing point, but they are often borne on some of the earlier formed secondary filaments and are often abundant a very short distance behind the growing tip of a branch. They are also often produced on the younger filaments of much older cortical branch systems, and it is not uncommon to find procarps and mature cystocarps close together in the same branch system of cortical filaments. In the development of the procarp the wall of the terminal cell of a young cortical filament becomes thickened, particularly about the distal parts of the cell, and a terminal cylindrical outgrowth appears (*Figs. 9, 10*). This outgrowth, the trichogyne, increases in length until, in the mature procarp, it may reach 150 mic. in length, projecting beyond the gelatinous matrix of the frond. In all immature procarps the protoplasm of the trichogyne was continuous with that of the carpogonial cell. No entirely mature and unfecundated procarps were seen. Many mature procarps with attached sperms were found, and in these the protoplasmic contents of the trichogyne were always much constricted and often broken at intervals and separated from the contents of the carpogonial cell.

The carpogonial cell and the trichogyne are from the first devoid of floridean starch.

The cell immediately proximal to the carpogonial cell is specialized as an auxiliary stalk cell (*Figs. 10–16, a*). During the earlier stages of the development of the trichogyne, the cell is scarcely to be distinguished from the sterile cells of the filament. As the trichogyne approaches maturity, the auxiliary stalk cell rounds up, becoming wider than the adjacent cells, and it may be further distinguished from the proximal celis of the filament by its dense cytoplasm, and by containing very little floridean starch. It undergoes little further change during the development of the cystocarp.

After fecundation the trichogyne soon withers, but the basal portion may persist for a considerable time (*Fig. 14*). Its remains may occasionally be seen in the half developed cystocarp, but never when the cystocarp is mature.

The fecundated carpogonial cell soon divides transversely into two unlike cells. The proximal cell thus formed is almost

cylindrical, averaging 10.7 x 8.6 mic. It remains sterile, forming a stalk cell, or placenta (*Figs. 12–16, S*). It contains a distinct nucleus, and has thin cytoplasm, appearing noticeably clearer than the adjacent cells. Its cell wall is often much thicker than that of the auxiliary stalk cell, or of the central cells of the cystocarp. Throughout the development of the cystocarp the cytoplasmic connections between the proximal cells of the fertile filament, the auxiliary stalk-cell, the stalk-cell, and the basal fertile cells of the cystocarp can be easily seen.

The distal cell formed by the first division of the carpogonial cell has very dense cytoplasm (*Fig. 12, c*). It soon divides again, transversely, and then each of the cells thus formed divides one or more times in planes perpendicular to the first division, forming thus an almost spherical mass of several cells arranged in two tiers (*Figs. 13, 14*). These form the central cells of the cystocarp. Branching gonimoblast filaments arise as outgrowths of these central cells (*Figs. 15, 17*). The cortical cells of the gonimoblast are very thin walled, and have dense cytoplasm and distinct nuclei. When the gonimoblast filaments reach their full growth the terminal cells become thick-walled, and their cytoplasm becomes very dense. Eventually the contents of each of these cells escapes as a spore, leaving the empty cell-wall still attached to the gonimoblast filament.

As a secondary result of the fecundation of the procarp, sterile filaments, resembling the ordinary cortical filaments, arise from the cells immediately proximal to the auxiliary stalk-cell. These filaments correspond to the pericarp which completely surrounds the cystocarp of many Rhodophyceæ, but in this case they never form more than an irregular and imperfect covering about the base of the cystocarp.

It will be seen that the structure and development of the cystocarp is essentially that found throughout the Nemalieæ. The general features of the reproduction in this group were described by Bornet and Thuret in the year 1867 (Bornet, E., and Thuret, G., Recherches sur la fecundation des Floridées, Annales des Sciences Naturelles, Series V., 8: 141–145. 1867) sincewhich time the phenomena of reproduction have been studied more or less in detail in numerous plants of this group. (See Janczewski, Notes sur le Developpement du Cystocarp dans les Floridees,

Mem. de la Soc. de Cherbourg, **20**: 109–144. 1876; Bornet, E., and Thuret, G., Etudes Phycologiques, 63, *Plate 32*, 1878; Wille, N., Die Befruchtung von *Nemalion multifidum* (Web. and Mohr) J. Ag., Berichte der Deut. Bot. Ges. **12**: (57). 1894.) In *Nemalion multifidum* Wille (*l. c.*) traced the passage of the male nucleus down into the carpogonial cell, and its fusion with the nucleus of the latter.

Schmitz and Hauptfleisch (Schmitz, Fr., and Hauptfleisch, P., Helmenthocladiaceæ, in Engler and Prantl, Die Natürlichen Pflanzenfamilien) in their classification of the Nemalieæ lay stress on the position of the carpogonial branch, whether it is terminal on one of the younger cortical filaments, or borne laterally upon one of the intermediate cells of a cortical filament. In this they are followed by De Toni. (De Toni, J. B., Sylloge Algarum, **12**: 76. 1897.) In the first class they place *Nemalion* and *Trichoglœa*, and in the second class *Helminthocladia* and *Liagora*. It is to be noted that, while the procarp appears terminal in *Trichoglœa lubrica*, it is borne only on one of the secondary filaments, which are themselves of lateral origin, and hence the difference in this case is rather that the carpogonial branch in *Trichoglœa* is long, approaching the length of the sterile cortical filaments, while in *Liagora* and its allies the carpogonial branch is very short, and hence the procarp is almost sessile. Whether the apparently terminal procarp of *Nemalion* is to be similarly interpreted, can be determined only by observation.

It has been noted that in *Trichoglœa lubrica* there is a rudimentary pericarp. In *Nemalion* the cystocarp is naked, while in the other genera of the Nemalieæ there is an abundant pericarp, often produced by outgrowths from the primary cortical filament upon which the carpogonial branch stands.

It will thus be seen that in the structure of the vegetative tract *Trichoglœa lubrica* agrees very closely with the genus *Liagora*, while in the reproductive tract (and especially in the structure of the cystocarps), it most nearly resembles *Nemalion*, holding, however, in some respects a position intermediate between *Nemalion* and the three genera, *Liagora*, *Helminthocladia* and *Helminthora*.

EXPLANATION OF PLATES.

The figures on Plate V. are from photographs and photomicrographs, those in Plate VI. are from drawings made with the Abbé camera.

1. Entire plant of *Trichoglœa lubrica* (Harv.) J. Ag., about three fourths natural size. After photograph by C. J. Hibbard.

2. The growing point of a branch of the frond, × 120.

3. Detail from somewhat older portion of the frond, × 65. *p*, primary medullary filament; *s*, one of the smaller medullary filaments; *s′*, a younger filament of the same type; *c*, young cystocarp.

4 A single mature cortical branch system, × 25.

5. An antheridial cortical branch system, × 80. *p*, primary medullary filament; *s*, one of the smaller medullary filaments; *s′*, a younger filament of the same type; *c*, young cystocarp.

6. Cross-section of mature portion of frond, × 32. Part of the calcareous incrustation has been removed with hydrochloric acid. *l*, remains of the deposit of lime.

7. Detail from cross-section of medullary region of mature frond showing the two kinds of medullary filaments, × 116.

8. Detail of antheridial cortical filament, × 438.

9–16. Stages in the development of the protocarp and cystocarp. *a*, auxiliary stalk-cell; *s*, stalk-cell; *c*, fertile portion of carpogonial cell after the cutting off of the stalk-cell.

9. Young procarp, × 600.

10. Procarp with the trichogyne about half developed, × 475.

11. Mature and fecundated procarp, × 475.

12. Carpogonial branch after the first division of the carpogonial cell, × 600.

13. A somewhat later stage in the development of the cystocarp, × 700.

The distal segment of the carpogonial cell has divided a second time transversely, and the segments are dividing longitudinally. The growth of pericarp filaments has begun.

14. A developing cystocarp, slightly later stage than *Fig. 13*, in position among the surrounding cortical filaments, × 400.

15. Young cystocarp with the developing gonimoblast, × 475.

16. Mature cystocarp, × 438. From section 6.66 mic. thick.

17. Detail of developing gonimoblast, × 640.

P

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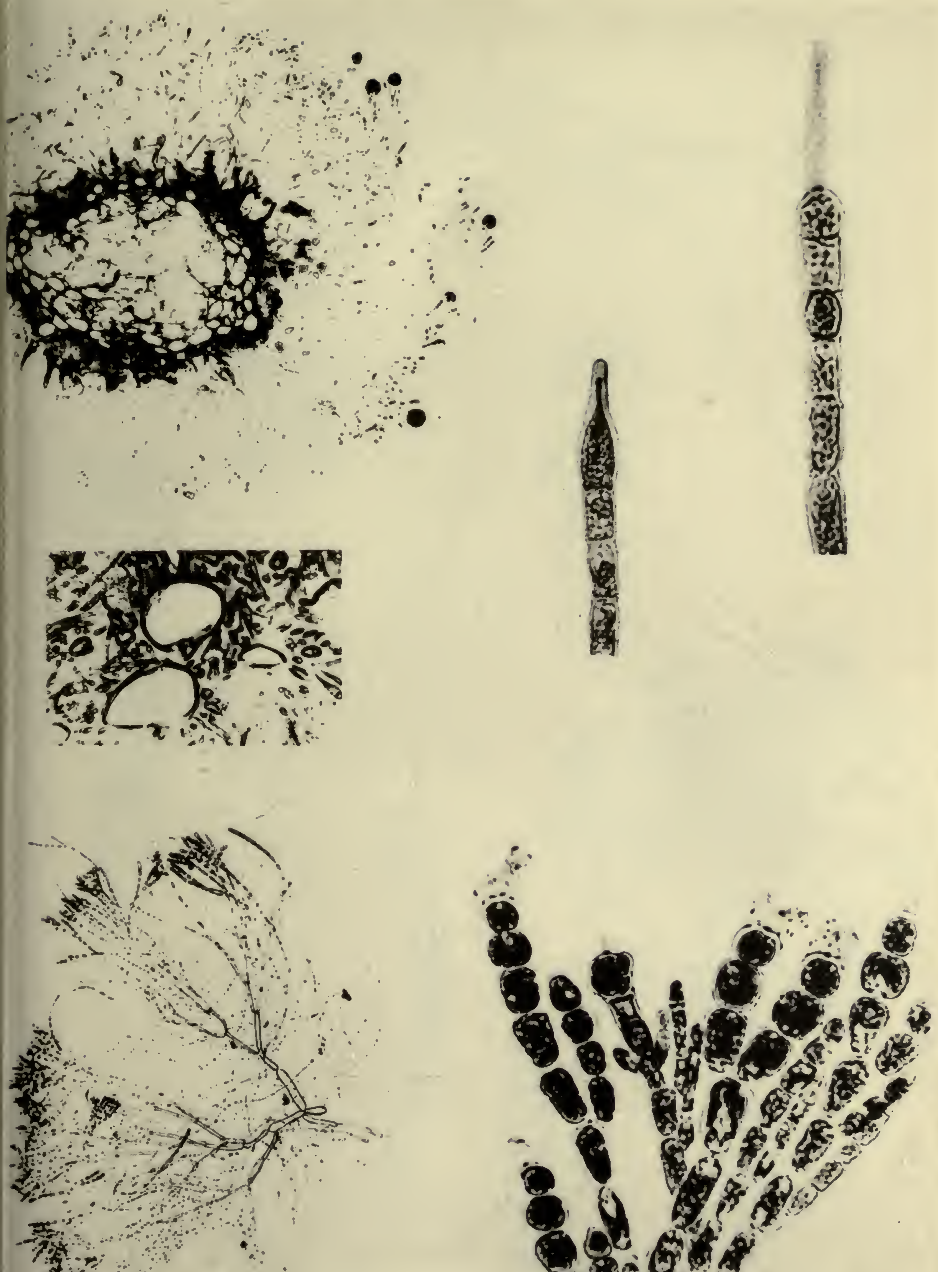

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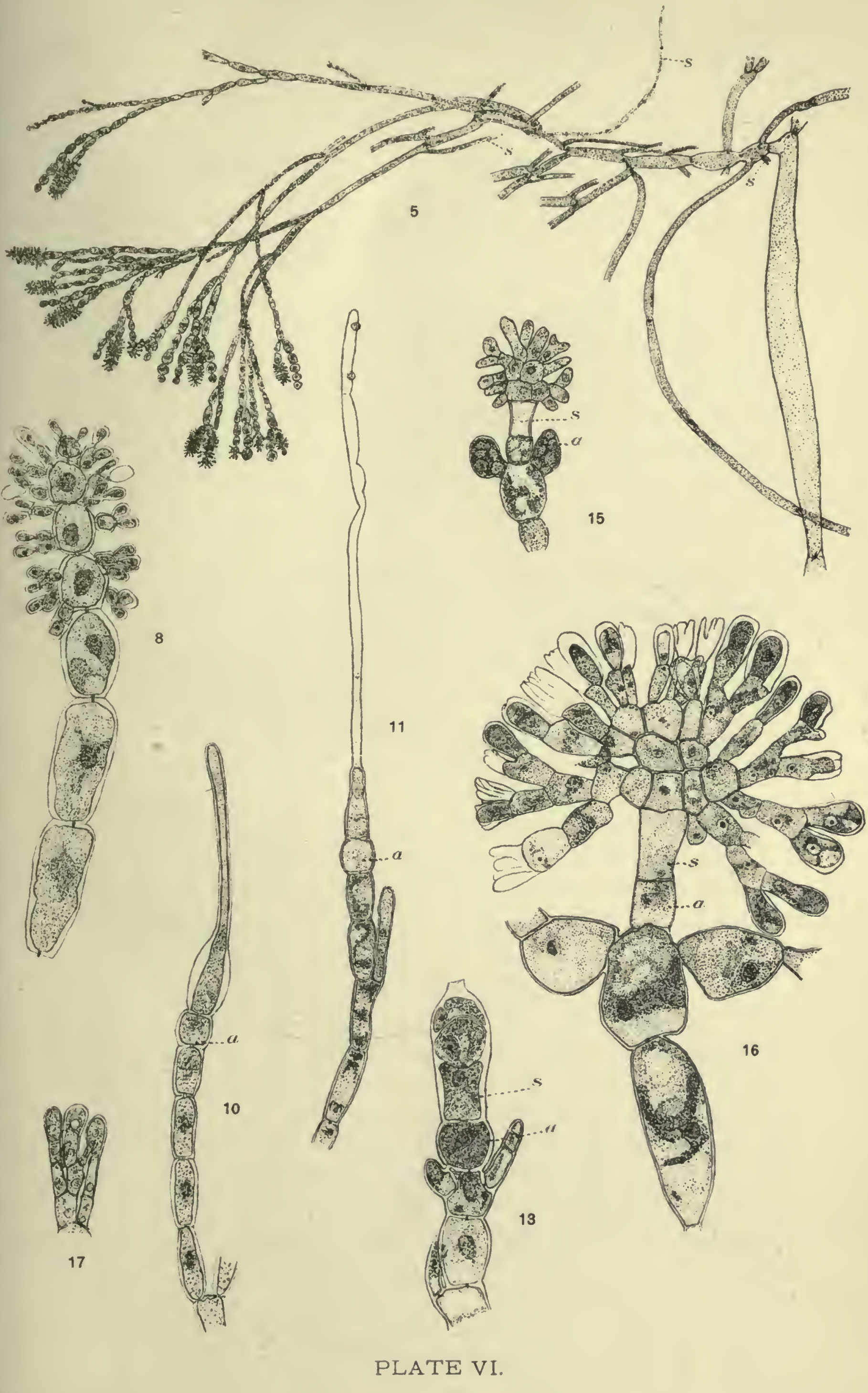


PLATE VI.

HELIOTYPE CO., BOSTON.

III. OBSERVATIONS ON PELVETIA.

F. L. Holtz.

Pelvetia fastigiata (J. Ag.) DeToni, is a marine alga found distributed along the western coast of the United States and British Columbia. It grows in beds, attached to the rocks, between high and mid tide, and is, therefore, daily exposed to the air for several hours (*Pl. VIII.*). The material studied for this paper was collected by Miss Josephine E. Tilden on Vancouver Island, in June, August, and December, 1901, and was preserved in formalin.

There was originally some doubt in the minds of systematists whether this plant was a *Pelvetia*. It has been called *Fucus fastigiatum* (J. Agardh, Symb., I., 3) and *Fucodium fastigiatum* (J. Agardh, Sp., I., 203). The difficulty of placing it arose from the uncertainty as to the number of eggs it forms in the oögone, and this point was left undecided by DeToni. Dr. W. A. Setchell seems to have been the first to demonstrate the true generic position.*

External appearance.—*Pelvetia* is one of the smaller wracks. It is 10–20 cm. in height, and springs from a disc-shaped holdfast with dichotomous branches repeated till it presents a fascicled appearance. In well-developed plants the stipe branches immediately above the holdfast, and the branches subdivide again but a short distance farther on, so that at first sight there seems to be several fronds arising from the same holdfast. The regular dichotomy near the base may be further confused by adventitious shoots springing from near the base of the main stipe. In the material at hand but one main stipe was observed arising from a holdfast. The front may undergo dichotomy a dozen times before the terminal laminæ are reached. The internodes are longer toward the top. The coördinate branches keep about equal growth, though a few may remain smaller and hence appear like lateral branches (*Pl. VII.*).

*Setchell, W. A. Phyc. Bor. Am., No. 176.

The holdfast is a disc about 1 cm. across, and may be somewhat lobed at its margin, due to protruding masses of cells that are somewhat rhizoid in function, tending to clasp the irregularities of the substratum. The under surface appears slightly rough and pitted.

The mature stipe is elliptical in cross-section, but not winged. It is thicker and rounder at the holdfast, but flattens out into a ribbon-like shape farther up, and widens and thickens slightly toward the top. The average width at the bottom is 3 mm., and at the top 4 mm. It is about 1 mm. thick at the base and 2 to 3 mm. at the top. It is tough and coriaceous below, soft and fleshy above.

The laminal portion is usually two-lobed, and is differentiated externally from the stipe by a rather abrupt thickening and by the fact that it is generally dotted over with the elevated ostioles of the conceptacles, giving it a warty appearance. The lamina is also more translucent than the stipe. The lamina is wedge-shaped; the lobes into which it is divided in its upper half are tapering with rounded points. The laminæ have the softest tissue in the plant. There are usually laminæ in all stages of development, on a main branch, from cylindrical stipe-like laminæ to old, flat, warty, fruiting ones.

The color of the plant is nearly uniformly light brown, the older parts being a little darker, especially the lower stipe. The surface, except on the fruiting lobes, is smooth and shining. The plant is very elastic.

Adventitious shoots may arise on any part of the surface of the plant. They occur chiefly where old wounds have healed over. For instance, where a branch has been torn of, or a lamina cut off, or where incisions have occurred, here may be found proliferations arising as small outgrowths. Sometimes only one may occur, again a dense cluster. Some of these develop into large shoots.

The conceptacles may easily be seen by looking through the translucent lamina toward a strong light. They are thickly scattered over the lamina and its lobes. There is a rude arrangement of the conceptacles in rows running approximately perpendicularly across the axes of the lobes. There are 150 to 200 conceptacles on a lamina. They are developed in the younger tissue at the ends of the lamina lobes. Hence the more mature conceptacles are found some distance from the tip

of the lobe. Occasionally conceptacles are scattered over the stipe. These are generally less mature than those on the lamina above. They may be formed here adventitiously after those of the lamina, or else they may have been formed before or at the same time as those on the lamina and were then arrested in their growth.

The conceptacles cause a small papilla in the surface above them. This can be easily seen with the naked eye, as can also the ostioles themselves, which appear as little pits in the tops of the papillæ. A well-developed plant may have half a dozen main branches and fifty to sixty laminæ.

When placed in fresh water the mucilage of the interior of the plant absorbing the water, causes the laminæ to burst. The distending pith pushes its way out and the cortex curls back, showing a state of tension between interior and exterior. As a result the cortex pulls off from the pith. The conceptacles then appear plainly as little spherical masses projecting from the inner side of the cortex. This intimate union of the conceptacle with the cortex might be taken as evidence of the cortical origin of the conceptacles, which is the case, as will be shown. In *Plate VII* conceptacles are visible on the inside of the cortex in the bursted laminæ.

Minute anatomy, tissues in general.—*Pelvetia* shows considerable differentiation of tissues, though not so much as many other algæ, not even so much as some of the other Fucaceæ. *Fucus* shows greater differentiation in having a midrib and air vesicles in addition to the structures possessed by *Pelvetia fastigiata*.

There are three principal tissues in the body of the plant. The epidermis, cortex and pith comprise the main bulk of the body. In the holdfast, however, no real pith cells are found.

Epidermis.—The epidermal tissue of *Pelvetia fastigiata* consists of a layer of prismatic cells elongated radially to about twice their shorter diameters, which are about equal. The epidermis is best developed in the stipe and lamina. Seen here in surface view the cells present a roughly quadrangular or polygonal outline. The epidermis is shown in longitudinal and cross-sections in *Figs. 1–3*, *Pl. IX*. The inner end of the epidermal cells and their radial walls are thin, while their free surface walls are convex outward. The surface of the epidermis is covered with a cuticle, thick and striated. This

cuticle is a common sheath to the whole plant. It is depressed into the crevices between the cells and is therefore wavy in section. It peels off in places. It shows a different, generally weaker, staining reaction from the regular cell wall. The wall underneath the cuticle is thin. The cuticularized epidermis probably is useful in preventing evaporation when the plant is exposed between tides. The hygroscopic nature of the mucilage within no doubt plays a very important part in this respect.

The epidermal cells are densely gorged with chromatophores. These are yellow, highly refracting grains of oval shape. As the function of the epidermis is assimilative as well as protective, the question arises, may not the convex outer walls of the cells aid in condensing the light that is necessary for assimilation (Kerner)?

The epidermal cells have the power of dividing radially and periclinally, cutting off basal cells that are added to the cortex and cause growth in thickness. The division in planes transverse to the axis of the plant provides for the elongation of the plant. This cambium-like nature of the epidermal cells is also seen in the origination of a meristematic layer where a conceptacle is to be produced (*Pl. XI.*, *Fig. 17*), and again the growing point is an epidermal cell (*Pl. X.*).

Cortex.—(*Pl. IX.*, *Figs. 1–3*, *5*.) Below the epidermis are six or seven rows of cells of varying size and nature, differing more or less from the epidermal and pith cells, and agreeing in a general way in not being greatly elongated and in having a large number of chromatophores. This tissue is the cortex. (The epidermis is by some writers included under this name.) The cells of the cortex are arranged with considerable regularity in vertical, radial and concentric rows. The regularity of shape and size tends to diminish towards the pith.

The row of cells immediately beneath the epidermis is composed of the basal cutoffs from the epidermal cells. They are cuboidal cells of a diameter equal to the width of the epidermal cells. They, like the outer cells, are gorged with color bodies. The second and third concentric rows of the cortex are, in cross section, of equal diameter, but a little larger than the row above. In longitudinal section it is seen that these cells are generally respectively two and four times as long as the basal cells of the epidermis. Some of the cells also show this larger size in cross-section. These cells seem still to have the power

of growth; and to some extent they divide both radially and vertically, but not tangentially. These two rows of cells also have rather thin walls, although there is some thickening at the angles. They are also densely packed with chromatophores.

Below the above-mentioned cells are three or four (five) concentric rows of cells that pass over into the pith on the inner side. Their walls are considerably thickened with a gelatinous substance, which, however, is firmer and denser than that of the pith. These walls stain deeply. The cells of these rows contain color grains but in more loosely disposed masses. The protoplasmic sac is more easily seen around these masses of chromatophores than in the outer cells. These cells have nearly the same radial diameter as the cells in the second and third rows, but are generally twice as wide tangentially and twice as long vertically as those of the third row. There is more or less variation in the number of rows of each of these different sizes of cells. These elements may be diagrammatized as in *Pl. IX., Fig. 5.*

The original walls between these cells thicken as the pith is approached. The cells lose their rectangular shape more and more towards the pith till at last it is sometimes difficult to distinguish them from the more cylindrical pith cells. The cells remain in communication through pits, the cells anastomosing frequently. The longer cells form transverse septa, which are often oblique to the lateral walls. These septa are never thickened, but remain very thin and, to all appearance, allow protoplasmic communication (*Pl. IX., Fig. 12*).

Pith.—(*Pl. IX., Figs. 1–5.*) The pith of the stipe and lamina is distinguished by the fact that the cells are separated widely by intercellular jelly, which in the lamina is from two to three times as thick as the diameter of the cells imbedded in it, less thick in the stipe (1–2). The pith is also marked off by the jelly not staining as deeply as the intercellular matrix in the cortex. With some stains, fuchsine for example, the stain may be almost completely removed by washing, leaving the inner wall of the pith cells colored. Pith cells are slightly compressed corresponding with the flattening of the stipe or lamina (*Pl. IX., Fig. 1*). They are nearly as wide as the average width of the cortex cells, and are about as long or a trifle longer than these. They are crossed by delicate septa (*Pl. IX., Figs. 2, 4, 13*). Pith cells are joined into vertical rows or filaments

which wind about and intertwine somewhat with each other. These filaments anastomose frequently and are often dichotomously divided (*Pl. IX., Figs. 3, 4, 13*). The cells of the pith in the central part of the stipe or blade are of nearly uniform diameter throughout their length and are regular in shape, except at anastomosing plexi and near the cortex where they are subject to distortion in shape and to displacement.

The pith cells contain a few chromatophores collected into a little pellet near the middle of the cell. The protoplasmic contents show up well and numerous refracting grains of reserve material are seen.

The gelatinous intercellular matrix swells up greatly when the plant is placed in fresh water. This causes the lamina to burst open, beginning at the more tender tip of the lobes in the young laminæ. The stipe having a firmer cortex and also proportionately less intercellular gelatine, does not burst, though it swells some.

Anastomosis and Pits.—Anastomosis is seen best in the pith cells (*Pl. IX., Figs. 2–4, 12–14*). Sometimes two filaments will simply be bent toward each other, touching with their convexities (*Fig. 2*). At this point there is no intercellular jelly separating the cells. A thin communicating plate is between the cells in contact, and the protoplasm in these cells sends out branches that meet at the plate. At other times the anastomosing cells send out lateral protuberances, which passing through the jelly, meet and form a pit at the point of contact (*Figs. 4, 13, 14*). Probably these protuberances were not formed before the pit was formed, but are the result of the growth and modification of shape of the cells which took place after the pit already was made. Judging from the conditions in the cortical layers, these pits are simply the original fission walls left unthickened at these spots (*Fig. 12*), while at other points the contiguous cells were forced apart by the development of the gelatinous middle lamella between the two cells, however, leaving the cells in contact at the pits. The pits at lateral anastomosing points are smaller than at the ends of the vertical cells. The pits do not stain as deeply as the rest of the cell wall, but this might be due to their greater thinness. They are sharply marked off in the walls of the pith and the inner cortex cells. They are round or oval plates which in optical section are of uniform thickness, not lenticular. They show less definition of

shape as the outer cells of the cortex are approached. Here they appear to be simply the original dividing wall. They can, however, be located by the protoplasm apparently running right through the wall at these places. This apparent communication of the protoplasm of adjoining cells was observed as far out as the second layer of cells below the epidermis. Farther out this could not be seen on account of the chromatophores. But probably even the epidermal cells communicate with each other. The concentrated sulphuric acid test showed that the plates were dissolved as well as the rest of the wall. No positive proof was found that the pits were perforated, no threads of protoplasm having been observed, as would indeed be difficult with the extreme thinness of the plates. But the symmetrical arrangement or attachment of the protoplasm on both sides of the pits leads one to suspect very strongly that there is communication. By plasmolysis the protoplasm draws away from the cell wall at all other points than the pits (*Fig. 13*). It remains attached here and extends in ropes through the cells and seemingly through the pits. The protoplasm often branches to lateral pits (*Fig. 14*). When the pith cells are swollen in fresh water the protoplasm is frequently torn off from one end of the cell, away from a pit, owing apparently to the elongation of the lateral wall as well as the gelatinous matrix. In such cases the pit curves in toward the loosened protoplasm (*Figs. 12, 14*).

Iodine is the most satisfactory stain to use in studying pits. The protoplasm is stained and its attachments may be studied. Pits and anastomosis may be nicely studied by removing some of the protruding pith from a lamina that has burst in fresh water. By flattening the gelatinous mass under the cover glass the pith cells and their pits show up well, even unstained, though better if differentiated with stains for walls and for protoplasm.

Anatomy of Holdfast, Stipe and Lamina. — The above matter on the tissues in the body of *P. fastigiata* needs some modification and addition when the holdfast, stipe and lamina are considered separately.

Holdfast. — In a vertical section through a holdfast it is seen to be composed of approximately regular, ascending rows of cells; those near the central part more vertical; those near the border of the holdfast curving out as they go down. There is a marked difference between the cells in the middle and those

in the peripheral part. The former are irregularly quadrangular in outline in both vertical and cross-section. Their diameters in cross-section are equal (*Fig. 6*). They are more regularly disposed in rows than the cells in the marginal parts. The cells of the holdfast have walls of good thickness, composed in part of the usual mucilaginous substance.

Taking the central part of the holdfast (*Fig. 6*), the lowest cells are dead and empty and partially disintegrated into mucilage. Clefts arise among the still living cells from this disintegration. Gaps are also caused in this way in the body of the holdfast. Here and there individual cells at the bottom have a disc-like lower surface as if they had a holdfast of their own. The decay of the cells near the central part of the holdfast extends not more than one or two cells deep. The next few rows of cells are slightly flattened parallel with the base of the holdfast. The succeeding rows of cells become gradually elongated in a vertical direction till, at the tenth or eleventh row, a rapid differentiation begins with cells elongated in the vertical direction to two or four times their horizontal diameter. Evidently the stipe begins at this zone.

The peripheral portion (*Fig. 7*), as was stated above, is composed of rows of cells descending obliquely from the axis of the stipe. A vertical section through this part shows that these rows of cells branch dichotomously in the horizontal plane as they go down and outward. The cells decrease in length as one follows the dividing branches, till a zone is reached in what corresponds to the cortex of the stipe. Here the ultimate dichotomous divisions of the main strands form a meristem of small cells. The cells of this meristem run in straight rows perpendicularly to the surface of the holdfast. They are in active division. This meristematic layer enables the holdfast to grow in thickness and also to form the rhizoid-flaps on its edge. It is about eight to ten cells deep. In the specimen examined the basal cells, three to five deep in this part of the holdfast, showed advanced disintegration. The epidermal layer near the lower edge also was in a similar condition. But the cells of this layer are more resisting and persist alive after the two rows beneath are already dead. Probably the mucilage derived from the disintegration of these basal cells is useful in attaching the plant to the substratum.

The cortical part of the holdfast passes without any marked change into that of the stipe. The epidermal cells however are not elongated as much radially as those of the other parts of the surface of the plant. It is covered with a cuticle, thicker than on the stipe or lamina.

Cross-sections of the central part of the holdfast show (*Fig. 8*) that the vertical rows of cells seen on vertical section are not disposed in any regular order. The intercellular substance is not nearly as abundant as in the stipe. Toward the margin of the holdfast the cells show power of dividing. Here we find, interspersed with cross-sections of the vertical rows, sections through cell rows slanting up toward the axis of the plant. Still nearer the outside we come upon the meristematic zone. Here are principally slanting rows of cells dividing dichotomously in the radial direction. These divisions repeat the dichotomy, running directly to the surface.

All the living cells in the holdfast have chromatophores. The central cells contain but few grains, the cortical are crowded with them.

Stipe. — But little need be added here to what has been said under tissues in general. The young stipe has a nearly cylindrical structure, with a slight notch on the end where a growing point is situated. No differentiation is noticeable between stipe and lamina. Older stipes become flattened, partly on account of the flattening of the cells parallel with the longer axis of the cross-section, but more on account of the greater growth toward the thin margins. A cross-section of an older stipe shows two principal planes of fission by the arrangement of the cells in rows parallel with the major axis of the section and the other obliquely across this axis. This is especially noticeable in the pith. The cortical cells show a distinctly concentric arrangement (*Fig. 1*). The only differentiation seen in cross-section is that the pith and inner cortex cells near the ends of the ellipse are somewhat larger than those of the central part. This differentiation however does not even suggest a midrib. Longitudinal sections of the stipe, cut parallel to the flat surface, show a similar appearance, except that the typical pith cells are reached sooner in passing from the surface along the minor axis. The appearance of the cells in both cross and longitudinal sections has been discussed under tissues in general.

Lamina.—The general tissues of the stipe and lamina are so

similar that no change is noticeable in passing from one to the other. In the lamina proper, however, the pith cells branch more and the rows of cells have a more meandering course, and there is more anastomosing. The intercellular jelly is developed here more than elsewhere in the plant. Due to this and some to the branching of the cell rows the blade is much thicker than the stipe.

The cortex and epidermis are similar to those of the stipe. The crowding growth of the conceptacles disarranges the orderliness of the cell arrangement in the cortex and epidermis. Cross and longitudinal sections of the lamina resemble those of the stalk closely, except for the differences just mentioned, and for the conceptacles (*Fig. 3* shows a partial cross-section of a lamina).

The growing point.—In the tip of the maturer laminæ no definite growing point can be found. There still is some growth and cell division going on here in the outer cortical cells, and in a mature lamina this is probably the youngest and tenderest portion. It is here that the lamina begins to burst when placed in fresh water. Even at the sinus between the lobes of the lamina no growing point can be found in older laminæ. This is the place where the growing point once was. But the growth seems to have stopped here first and continues for a time longer toward the ends of the lobes.

If a young frond is examined, one in which there is as yet no difference between stem and blade, a slight notch or dimple is visible at the top. This notch deepens in older fronds, and if a section is made through the somewhat flattened stipe, parallel with the flat surface and through the axis of the frond, a large apical cell is seen at the base of the sinus (*Pl. X.*, *Figs. 15*, *16*). This apical cell is an epidermal cell. It is in the shape of a truncated pyramid, with the truncated end to the top or pointing outward. The apical cell is two or three times as large as the other epidermal cells, and is otherwise markedly distinguished by great richness and granularity of contents, and by the absence of chromatophores. The adjacent cells share these characteristics to a less degree. They show a diminution in the granularity of the protoplasm, and color grains begin to appear in all but the latest cutoff.

The apical cell, as seen in vertical section, cuts off daughter cells in succession, a lateral, then a basal, and then a lateral

on the other side (see diagram, *Fig. 16*). The daughter cells quickly divide again and again, but more frequently in a lateral direction from the apical cell than downward. The cells in these lateral zones divide more rapidly in planes transverse to the axis of the lamina. In this way the zone of most rapid growth extends out laterally and upward from the apical cell and soon grows up ahead of the growing point. As a result there is the bifurcated lobe.

Differentiation into the long pith cells begins only three cut-offs below the apical cell. In the wings it does not begin so soon. The zone of cells in the wings retains its power of fission longer than the cells below the apical cell.

The cells of the epidermis and the cortical zone attain the characteristics of these tissues but a short distance from the apical cell.

The outer cortical cells throughout the plant are capable of dividing and seem to constitute a kind of cambium around the plant. This meristematic nature of the cortex is most highly developed in the lobes of the young lamina near the growing point. It is also well developed where conceptacles form and in the marginal parts of the holdfast.

The cuticular sheath that covers the whole plant is very thick over the delicate growing point, being about as thick as the length of the epidermal cells beneath it, no doubt serving as a protection.

It is customary to speak of the rows of cells in the plant as hyphæ. But when the origin of these cells is considered, that they are derived directly or indirectly from a single apical cell, the idea of their hyphal character seems a little incongruous.

On the development of the conceptacle.—As before noted the conceptacles show an intimate connection with the cortex. Sectional views prove the cortical origin and nature of these structures.

The first indication of the beginning of a conceptacle is seen to be the cutting off of a basal layer of cells from the lower end of a few adjacent epidermal cells (*Pl. V., Fig. 17*). These basal cells in turn divide periclinally and radially to form a little pad of meristematic cells beneath the epidermis, around which the cortical cell-rows are deflected. Directly over this mass of basal cutoffs, usually in the center, one or more epidermal cells begin to show signs of disintegration and collapse.

The walls of these cells stain more deeply than those of normal cells, the nuclei disappear and the chromatophores fuse together into a dark mass. The affected cells collapse gradually, beginning at the outer end. Often a little conical remnant of the shrunken cell may be seen on its basal cell. The walls and contents of the disintegrating cells change into a mucilaginous substance.

Thus far my observations agree with those made by F. O. Bower.[1] Bower states that the epidermal cell collapses, but that the basal cell persists, and that it sinks farther and farther into the cavity of the conceptacle, and that the lateral daughter cells of the central basal cell by their division form the lining wall of the cavity. He seeks to limit the disintegration of the epidermis at first to one cell and to make its basal cell the center of the whole process of the development of the conceptacle.

The serial sections made by me for the investigation of this matter do not show that the disintegration is thus confined to one single epidermal cell. Occasionally several will be equally far advanced in decay. Naturally one or the other of these may decay more quickly than the rest, producing thus a line of weakness and apparently a central axis about which the other decaying cells are grouped.

Again, it was not found that the basal cell or cells of the disintegrating epidermal cells persisted. On the contrary, they and several rows of cells below, perhaps five or six, share in this disintegration. It was frequently possible to make out the remains of the disintegrating cells in the mucilaginous mass to which they changed, and with which the cavity formed by their collapse was filled.

Neither did it appear that the basal cutoffs of the epidermal cells produced lateral daughter cells to line the cavity. It did appear that they divided chiefly periclinally and somewhat radially, forming five or six rows of meristematic cells, the outer rows disintegrating and forming the cavity; the deeper ones persisting and finally forming the inner wall of the conceptacle and giving rise to paraphases and the reproductive organs. Bower shows figures like *19*, *Pl. XI.*, in which the two cells, *b* and *c* on either side of the central basal cell *a*, might suggest that they were the lateral daughter cells of this basal cell. But

[1] Bower. Development of the Conceptacle in Fucaceæ. Qr. Jr. Mic. Sci. 36. 1880.

sections like *Fig. 21* are met with in which it is clearly seen that these lateral basal cells are not the daughter cells of the central basal cell *a*, but that they are the basal cutoffs of the epidermal cells above them. They are, therefore, coördinate with the basal cell *a*. The cells *e* and *f* are later cutoffs which the epidermal cells *g* and *h* succeeded in cutting off before becoming affected by decay. On account of less resistance from the cavity than on other sides these lateral basal cells grow usually in the shape shown in *Fig. 19*.

To summarize my conclusions on this point, the conceptacle originates by a few contiguous epidermal cells cutting off basal cells, *Fig. 17*, which are meristematic, dividing principally periclinally into half a dozen or more tiers of cells. Directly over this meristematic mass of cells, whether by the tension produced by the growth of the cells below, or otherwise, one or several epidermal cells begin to show signs of decomposition. The disintegration proceeds and the cells collapse (*Figs. 19* and *21*), and a cavity is begun. The disintegration spreads to neighboring epidermal cells and to the cells in the meristem below (*Figs. 21*, *23* and *25*). By their decay the cavity is enlarged. The deeper and marginal cells in the meristematic mass do not disintegrate, but in the end make the inner wall of the conceptacle, and give rise to paraphases and reproductive organs (*Figs. 27*, *28*, *29*). The mucilaginous remains of the decayed cells for a time fill the cavity, or protrude from its mouth, or close the mouth as a stopper. The diagrams, *Figs. 18*, *20*, *22*, *24*, *26*, corresponding respectively to *Figs. 17*, *19*, *21*, *23*, *25*, illustrate how it is possible to explain the development of the conceptacle without using Bower's central, persisting, basal cell theory. It is not probable that the development of the conceptacle in *P. fastigiata* is different from that in the closely related plants which he describes. Since this work by Bower is the principal reference we have on the development of the conceptacle in the Fucaceæ, and is generally quoted, it would be profitable for others to repeat these investigations.

Finally the disintegration stops, a healthy surface layer of cells then lines the cavity and the dead and mucilaginous cells are cast off into the cavity. Meanwhile the unaffected epidermal cells continue to divide and form their basal cells which pass into the cortex. This new cortical growth stops abruptly at the conceptacle. In this way the cavity is deepened and a

neck is formed to the cavity, this neck being composed of epidermis-like cells. The original cortical rows are at first slightly deflected around the forming cavity, but later become deeply invaginated and thus aid in the deepening of the conceptacle. The cells of these layers become flattened and lenticular in shape, and are arranged in concentric layers, three to five deep, around the cavity, thus forming a basket-like receptacle. The cells on the side toward the cavity are thin-walled and small, the outer cells are larger and have more intercellular jelly (*Pl. XI., Figs. 27–29*).

The cavity of the conceptacle is generally nearly spherical. Occasionally it is oval in shape with the longer axis in various directions. Where several conceptacles occur close together, there may be considerable distortion in their shapes.

The cortex over the conceptacle is slightly elevated by the growth of the conceptacle, but is gently curved again into the ostiole. The angle between the epidermis and the conceptacle is filled in with rather irregularly disposed cortex cells belonging to the deeper strata. The pith is sharply marked off from the flattened cortical cells around the conceptacles.

The mucilaginous remains of the disintegrated cells stay within the cavity for a considerable time, even till the reproductive organs form. Shreds and layers of this mucilage may also be found outside the conceptacle around its mouth. Frequently it closes the neck of the conceptacle like a stopper (*Fig. 27*). It seems to be finally partly absorbed and partly extruded by the paraphyses.

Bower thinks that the protrusion of the conceptacle into the pith is caused by the turgidity of the conceptable when filled and stoppered with the mucilaginous contents, the bulging being rather toward the softer and more yielding pith than toward the more rigid cortex, though even here it is noticeable. This explanation is insufficient, as it hardly seems possible that the conceptacle is closed tightly enough for the purpose, and especially since the greatest swelling of the conceptacle into the pith is in the later stages when the cavity has already begun to discharge or absorb the jelly and is no longer completely filled nor tightly closed. The principle of the arch might help to explain this protrusion of the conceptacle. As the cells in the wall of the conceptacle grow and multiply the arch which they form would create a distinct pressure on the surrounding tissue.

Paraphyses. — When the disintegration of the cells to form the conceptacular cavity is about finished, and while masses of mucilage still encumber the cavity, the first appearance of the paraphyses can be observed (*Pl. V., Fig. 27; Pl. XII., Fig. 38*). At this time the conceptacle is lined with one to three layers of thin-walled, ovally flattened cells, which are devoid of chromatophores or have only a few minute ones. The cells near the ostiole have more color bodies. These cells are filled with a granular protoplasm like the apical cell, though not so richly. The walls of these cells do not stain as deeply as the other cortical cells. The granularity referred to is evidently associated with activity in cell division.

Paraphyses arise as protuberances on the inner wall of some of the cells lining the conceptacle cavity. These protuberances may in young conceptacles project halfway across the cavity before they are cut off by a wall from their basal cells. The paraphyses appear at first in the lower half of the conceptacle. They very soon, even before they are cut off from their basal cell, begin to turn toward the ostiole.

As stated, the paraphyses in the main portion of the conceptacle arise as lateral buds from the cells in the wall of the conceptacle. The paraphyses at the upper end around the ostiole appear to form somewhat differently. They look as if they consisted of the unravelled or loosened cell rows of which the conceptacle wall is composed, and which crop out in the region near the top of the cavity (see *Fig. 29*).

As the paraphyses develop their end cells especially divide, though lower cells may do the same. The protoplasm remains in communication between cells. The protoplasm is slightly granular, nearly devoid of color bodies, except the end cells of the paraphyses about the ostiole. These are well provided with chromatophores, from which it would appear that their function is in part assimilative. Mature paraphyses consist, in the lower part of the conceptacle, of four or five cylindrical cells of almost uniform diameter. The end cell is tapering. The cells are about two or three times as long as wide. The paraphyses in the upper part of the conceptacle are more slender and their cells are shorter and more numerous, eight to ten.

The paraphyses are very numerous in a conceptacle. They are especially numerous and crowded at the top, though they are arranged here in regular, parallel order. In a few cases

paraphyses were observed projecting out of the ostiole, but not very much, only two or three cell lengths.

Reproductive organs. — The oögonia and the antheridia appear at about the same time. *Pelvetia fastigiata* has hermaphrodite conceptacles, and it is impossible to say that the oögonia or antheridia have special parts of the conceptacle on which to grow. Both may be found anywhere, except that the antheridia do not seem to develop as close to the ostiole as the oögonia sometimes do. Both organs arise in the same way as paraphyses, as buds from the cells that line the conceptacle.

Oögonium. — The oögonium may be recognized from the beginning by the fact that the cell which forms it from the first has darker contents than the rest of the cells in the conceptacle wall (*Pl. XII.*, *Fig. 30*). The young oögonia also are darker. The contents of the oögonial mother cell are composed of a very granular protoplasm. The oögone arises as a swelling along the whole free surface of the mother cell. Paraphyses and antheridial hairs do not occupy so much of the free wall of the mother cell. In other words, they start as mere slender buds. After extending into the conceptacle a distance a little greater than the thickness of the mother cell, a dividing wall is laid down, thus forming the oögone and its basal cell (*Figs. 31* and *32*). This wall is evidently porous, as the protoplasm of both cells seems to communicate through it. The pedicel for some time retains the opacity of its contents but later becomes more like the other cells in the conceptacular wall.

The oögonial cell continues dark, increasing in opacity as it matures. This fact, together with the other fact that the fixing and preservation in formalin is not a good way to prepare these tissues for cytological study, in truth seems to make staining more difficult. For this reason it has been impossible to carry out the study of the development of the oöspheres in a satisfactory manner. It was found, however, that if the sections were bleached from fifteen to twenty minutes in chlorine gas, stained in hæmatoxylin for twenty-four hours, and washed in acid alcohol till the stain of the other tissues was nearly removed, then the nuclei of the oögones could be seen. Methyl violet and acid alcohol also brought out the nuclei. In younger and more transparent oögones the nuclei can be made out without bleaching. In this way the oögone was traced from the uninuclear to the four-nuclear stage (*Figs. 31–36*). Thuret states

that *Pelvetia* oögones divide into eight nuclei and that six of these are afterwards destroyed. Not more than four nuclei could be seen in the material studied.

The ripe oögone contains two eggs. A delicate transverse partition is laid down across the middle of the oögonial contents. Each egg is hemispherical or round-conical in shape. The lower one is often more pointed than the other. Nuclei could not be distinguished with definiteness.

The oögone increases rapidly in size, swelling to an oval or pear-shaped mass which surrounds itself with a thick gelatinous wall (*Figs. 36* and *37*). The oögonial wall is at first not different from that of the basal cell, but it soon thickens and becomes gelatinous so that it swells in water. This thickening continues till in the older oögones the swollen walls present the appearance shown in *Fig. 37*. Stratification is sometimes seen in this wall.

In dehydrating specimens this gelatinous wall splits into two layers, a thin outer layer, and a thicker, firmer, more densely staining one. These layers often remain in contact at different points and generally at the base where both layers are thin (*Fig. 36*). These two layers are the exochite and meso(endo)chite of Farmer and Williams.[1] From their account it would seem that this double-layered condition is the normal. The observations in this case, however, showed that the division of the oögone wall into two layers was unnatural. For nothing like it was observable in sections mounted in water or glycerine. The splitting is probably due to the tensions set up in the dehydration and the thicker mesochite layer is probably formed by the shrinking of the gelatinous middle substance upon the inner layer of the wall, therefore, being denser and appearing more intensely stained. A similar thing is noticeable everywhere in the dehydrated and stained pith.

Antheridia. — It is generally possible to find oögonia in any section made through a mature conceptacle. The antheridia are often much scarcer, and search has sometimes to be made through several sections before they are found. There is, however, probably no conceptacle entirely without them. On the other hand, some conceptacles contain a great abundance of antheridia crowded in bunches among the oögones and para-

[1] Contribution to Our Knowledge of the Fucaceæ: Life History and Cytology.

physes. The antheridia are more numerous in the lower half of the conceptacle.

It is usually stated that antheridia in different Fucaceæ develop on branching hairs. This also is the general rule here. It is not necessarily always the case through, for antheridia can frequently be found not on branching hairs, but on simple pedicel cells (*Pl. XII.*, *Fig. 40*). The basal cells sometimes divide and later give rise to branches.

The antheridial hairs arise as papillæ or buds on the walls of the cells that line the conceptacle (*Fig. 39*). These papillæ are soon cut off by transverse walls. The outer cell elongates, divides and the lower of the two cells thus formed sends out a lateral bud near its upper end, which is later cut off by a partition. This process may be repeated several times along the main axis and the branches till a branching growth, not very dissected, is produced (*Figs. 39*, *40*, *41*).

The protoplasm of contiguous cells is in communication. Few minute chromatophores are found in these branching hairs. The granularity of the protoplasm is not very great as compared with that in the cells which develop the oögones.

Some of the end cells of the branching hairs increase in size, the nucleus divides into two, four, eight, etc., till about sixty-four nuclei are formed, so it is stated by authorities. In the material studied not so many could be counted, or estimated, only about forty. The nuclear division begins early, and different stages are all illustrated in the same section. The nuclei become somewhat smaller by successive division, this being especially noticeable in the earlier stages.

The antheridial cells are at first slender and somewhat pointed, but as the division within continues the cell becomes more and more rounded, usually oval in outline, slightly tapering at the top. The wall of the antheridium is at first thin. It soon thickens and becomes capable of swelling greatly (*Figs. 40* and *41*). The cell contents at first communicate with the basal cells, but later round up and draw away from the dividing wall. The spermatozoids stain quickly. They contain minute chromatophores. From one to six antheridia were observed on a single branching hair.

The plants studied for this paper were collected at the Minnesota Seaside Station by Miss Josephine E. Tilden, of the University of Minnesota. Thanks are due to her for them, and also for helpful suggestions given to the writer.

Methods: fixing and mounting fluids. — Material fixed and preserved in formalin was employed. This was washed in 30 per cent. alcohol, as fresh water alone caused injurious swelling of the laminæ. The material was then passed into higher per cents of alcohol to harden and dehydrate. The complete dehydrating seems to cause tensions in the body of the plant resulting in tearing apart of pith cells, the intercellular jelly giving way. But occasional very perfect pith sections may be thus obtained nevertheless, and by comparing with sections cut from 70 per cent. or 80 per cent. alcoholic material and mounted in water or glycerine the nearly natural appearance of these cells can be observed.

Most of the drawings were made from dehydrated material, and must therefore be somewhat unnaturally contracted. Where water or glycerine mounts were made and drawings from them, it is so indicated in the notes explanatory of the plates. The gelatinous walls swell greatly in glycerine (as compared with alcohol) but as the cross-sections of the lamina and stipe, for instance, have practically the same dimensions as the formalin material it may be assumed that the glycerine mounts give a truer picture of the tissues than do the balsam mounts.

Sectioning. — Most of the sections, especially the serial sections illustrating conceptacle development and the growing point, were made with a microtome from material imbedded in paraffine. After the work of hardening is once started this method is probably as rapid as any where imbedding is necessary. Some sectioning was done with a hand microtome, the 75 per cent. or 85 per cent. material being held in a pith clamp. Such sections were mounted generally in glycerine. These sections however showed a tendency to curl more than paraffine sections.

Staining. — A variety of stains were tried. Many of the ordinary wall stains proved entirely ineffectual. At length the following stains were selected as the best.

Fuchsine and methyl violet is perhaps the most generally useful. This mixture stains quickly and deeply. Washing cautiously in acid alcohol brings out different effects. Only a little washing leaves the gelatinous matrix slightly stained, the inner walls stain deeply, while the cell contents again take a slight coloring. Differentiation is brought out nicely, generally by more washing, in the conceptacular parts. The granular

inner cells of the conceptacle, the paraphyses, oögonia and antheridial hairs stain light red, the deeper cells of the conceptacle purplish, the pith cell walls dark red, while the color is all washed out of the matrix. Differentiation is also produced between different cortical layers, epidermis and cuticle and pith.

Methyl blue alone is a fairly good wall stain, but must be washed with care or it will all wash out. It also stains the chromatophores deeply. In this way the nuclei in the not too opaque oögonia may be located, they shining through as lighter areas in the dark mass of the oögone. Methyl violet is a quick stain. Over-stain and wash out as desired.

Bismarck brown was a very satisfactory stain for mapping out cell structure distinctly. It stains the inner wall of the cells (dark) brown, and the pith yellow. It is also useful in studying the structure of the conceptacle, the gelatinous sheath around the oögone being nicely brought out. It is a quick stain.

It may either be used dilute and allowed to stain longer, or more concentrated and then washed out till desired effect is obtained. Either way is good.

Hæmatoxylin dyes are better than carmine for nuclei. The most satisfactory results were obtained by bleaching the sections in chlorine gas for ten to fifteen minutes, then staining from one to two days in hæmatoxylin, then washing out till the walls and matrix were nearly clear, while the nuclei retained the stain longer. The chromatophores stain in hæmatoxylin and thorough washing is necessary to make the nuclei appear. Delafield's hæmatoxylin was found a good kind. The best effect was obtained by using a hæmatoxylin (brand unknown) that had been kept in solution at least ten years.

Iodine is very satisfactory for staining the protoplasm, and is very helpful in studying the pits between the cells, and in studying the contents of the conceptacular organs.

The staining was done on the slide. Rather concentrated dyes were employed. For alcoholic solutions of dyes 70 per cent. alcohol was used.

Description of Plates.

Plate VII.

Photograph of single plant of *Pelvetia fastigiata*. Shows holdfast, bifurcation of stipe and of laminæ. The warty appearance of some older laminæ is due to papillæ caused by conceptacles. Several laminæ have burst open through absorption of water, and show the conceptacles on the inner side of the cortex. About one half natural size.

Plate VIII.

Photograph showing bed of *Pelvetia fastigiata* on the rocks at Port Renfrew, exposed at ebb tide. This photograph was taken by C. J. Hibbard for the Botanical Department of the University of Minnesota.

Plate IX.

Anatomical detail: All drawings were made with the aid of camera lucida, diagrams excepted. All on this plate about × 250.

1. Shows part of the cross-section of stipe from epidermis to center of stipe.

2. Longitudinal section of stipe, showing cells with protoplasm, nuclei and chromatophores. The protoplasmic connection between cells is indicated. The cuticle covers the epidermis.

3. Cross-section of lamina. Shows the large amount of intercellular jelly in the pith region.

4. Longitudinal section of lamina, showing anastomosing pith cells. The space between them is filled with intercellular jelly.

5. Diagram of longitudinal and cross-section of stipe or lamina. Shows radially elongated epidermal cell. Beneath this are six or more rows of cortex cells and beyond these the pith. The cortex is shown arising as a basal cut-off of the epidermis. Previous cut-offs are shown in different stages of growth and division. Growth is principally in periclinal and longitudinal directions. The outer cells are more regularly rectangular, but become more rounded on the edges and corners toward the pith. The inner cortex rows finally become modified into long, cylindrical pith cells. The cells are separated farther by intercellular jelly as the pith is approached.

6. Vertical section through central part of holdfast. The lower part is shaded to show that the cells are dead, elsewhere also where such cells occur. The basal cells are flattened. The walls of the dead cells are gelatinous. The cells are shown with chromatophore masses to help indicate division. In the upper part the cells are elongated. Here the stipe begins.

7. Vertical section through periphery of holdfast, showing direction of cell rows. Also shows meristematic character of cells near edge. Disintegrating cells are shaded.

8. Cross-section through central part of holdfast.

9. Cross-section through holdfast nearer to the edge of disc.

10. Edge of holdfast, in cross-section, showing division of cells in this region.

11. Diagram to illustrate transverse and vertical dichotomy of the cells in the peripheral part of holdfast.

12. Diagrammatic view of cross-section of stipe or blade to illustrate protoplasmic communication in epidermal and cortical region. The chromatophores have been left out. Shows increase of intercellular jelly toward pith, crowding cells apart, except at the pits, showing formation of protuberances from adjoining cells.

13. Pith cells showing protoplasmic contents, nuclei and chromatophores. Shows end plates apparently permitting protoplasmic communication.

14. Shows lateral pits at anastomosing point of two pith cell rows.

Plate X.

Anatomical detail.

15. Growing point with apical cell dividing in two lateral and a basal plane, rapid multiplication of cells in the lateral regions; less rapid in the axial region. Rapid differentiation into pith in axial region; less rapid in the wings. Illustrates mode of bifurcation, × 375.

16. Same in diagram.

Plate XI.

Anatomical detail. Development of conceptacle, ×. 300.

17. Beginning of conceptacle. Shows basal cutoffs and disintegrating epidermal cells above them.

18. Same in diagram.

19. Later stage. Shows collapse of a central epidermal cell, remains of same appear as small cone on basal cutoff. Other epidermal cells are disintegrating, having however first succeeded in again cutting of a basal cell each, which have grown obliquely into the cavity formed by collapsed cell.

20. Diagram of same.

21. Later stage, more epidermal cells affected. Cavity filled with mucilage.

22. Diagram of same.

23. Later stage, basal cells disintegrating. Shows division going on in meristematic layer beneath.

24. Diagram of same.

25. Later stage. Shows cavity deepened, filled with mucilaginous remains of cells.

26. Diagram of the same.

27. Young conceptacle. Disintegration of cells has ceased. Their mucilaginous remains act as a stopper to the conceptacle. The neck is being formed by new layers of subepidermal cells. Paraphyses are beginning on the wall.

28. Later stage. Paraphyses and young oögonia have sprung from the cells lining the cavity. Chromatophores abundant near mouth, very few or small in lining cells. Cells in lining of cavity rich in protoplasm.

29. Nearly mature conceptacle with paraphyses, oögonia and antheridial branching hairs. Cells in wall of conceptacle have become flattened.

PLATE XII.

Anatomical detail. Reproductive organs and paraphyses, × 250.

30. Beginning of oögone and paraphysis. Oögone cell densely granular. Paraphysis begins as a more slender protuberance of cell in conceptacular wall.

31. Later stage. Basal cells have been cut off by oögone and paraphysis.

32. Similar. An oögone anlage preparing to form pedicel cell. Paraphyses elongating and dividing.

33. Nucleus of young oögone dividing in two. Protoplasm still in communication with that of basal cell.

34. Later stage, another division of nuclei. The protoplasm of the oögone has been forcibly torn away from that of basal cell, probably in dehydrating process.

35. Oögone in four-nucleated stage.

36. Four-nucleated oögone showing thickening of wall and separation of wall into thin exochite and thick gelatinous mesoendochite. The two layers still adhere in places. Wall remains thin at basal pit.

37. Mature oögone with two eggs. Was mounted in glycerine which caused swelling of walls.

38. Young conceptacle showing origin of paraphases as protuberances from cells lining cavity of conceptacle.

39. Young branching hairs, showing mode of branching.

40. Bottom of nearly mature conceptacle, showing oögone, paraphyses and branching hairs with antheridia. Antheridial protoplasm is shown in different stages of division.

41. Single branching hair in glycerine. Antheridia with sperms and swollen walls.

PLATE VII.

HELIOTYPE CO., BOSTON.

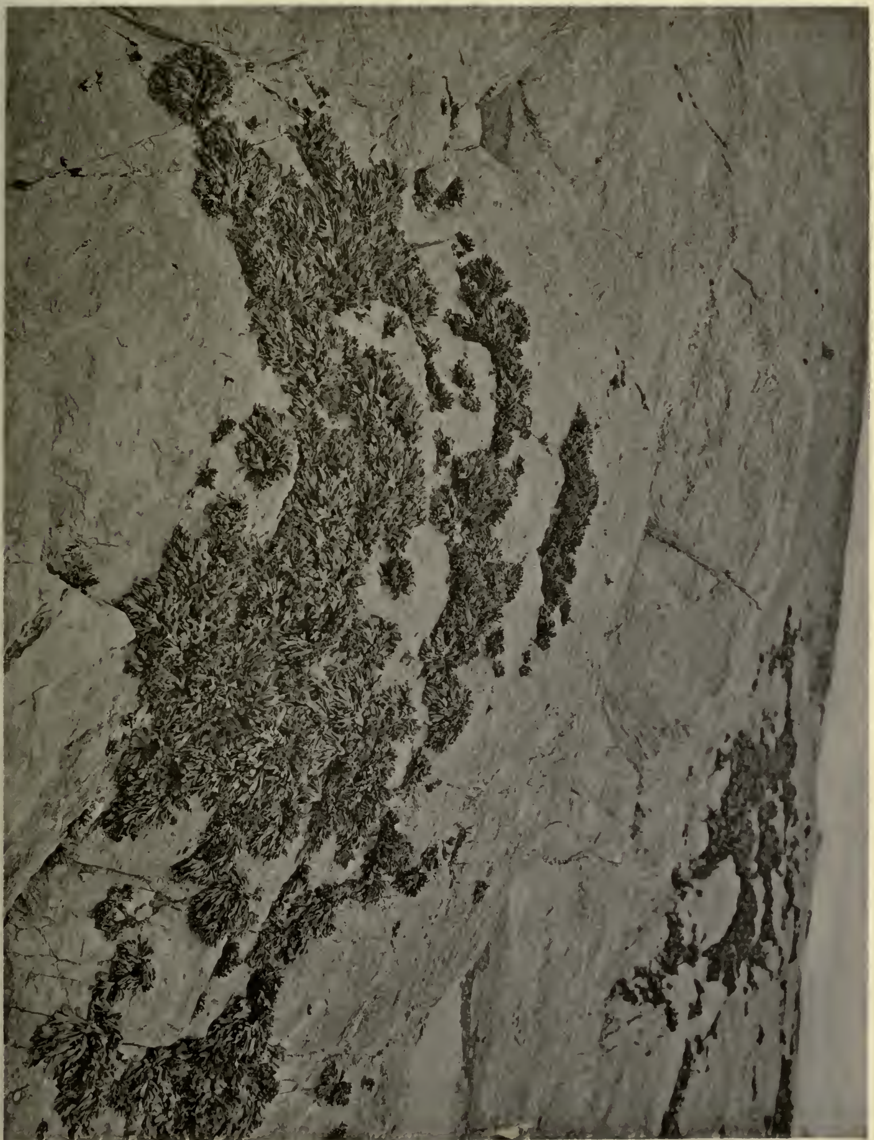
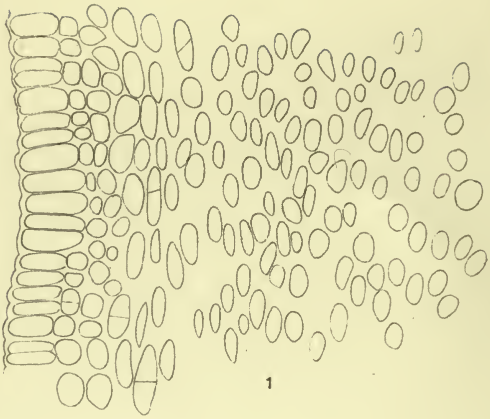


PLATE VIII.

HELIOTYPE CO., BOSTON.



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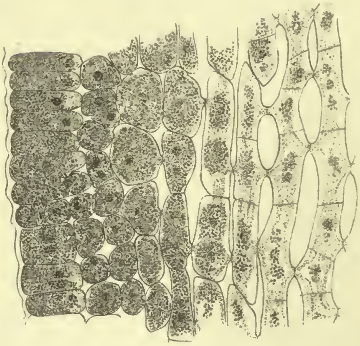

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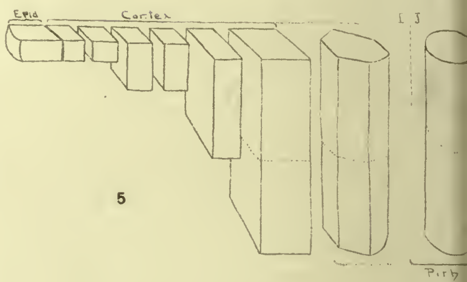

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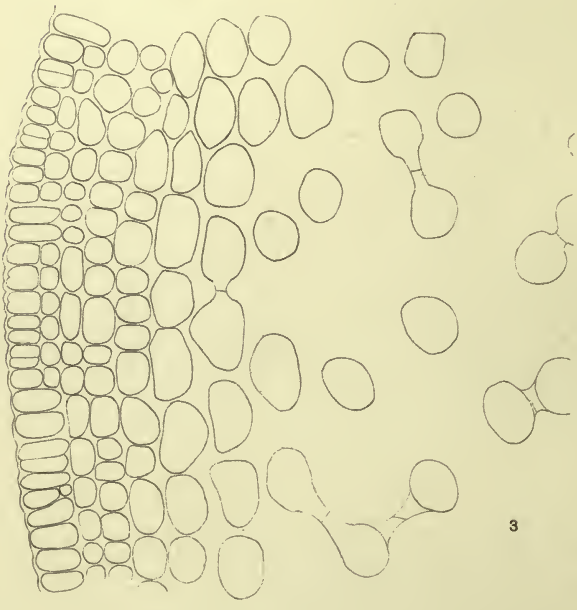

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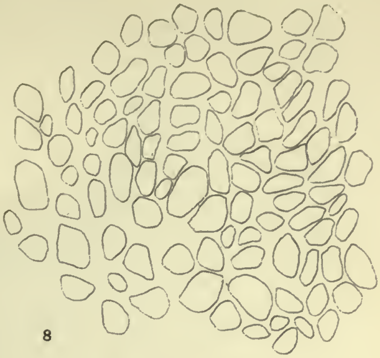

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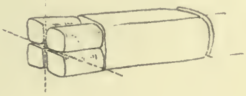

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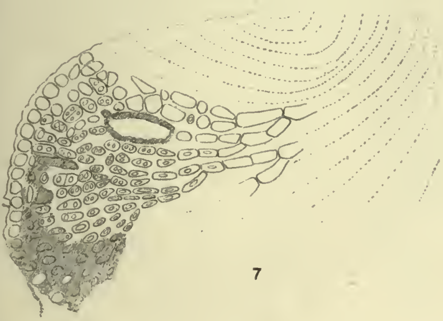

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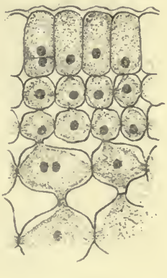

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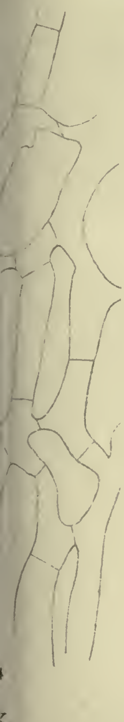

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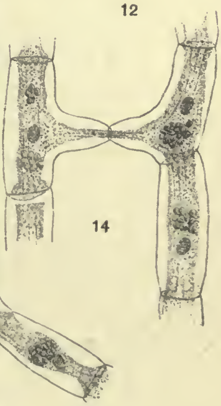

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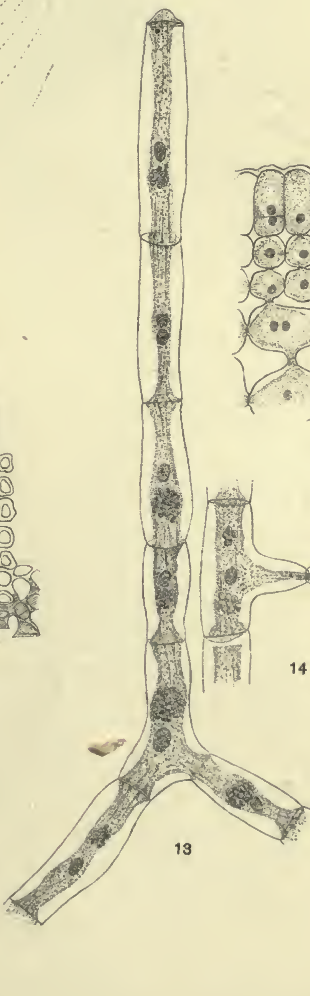

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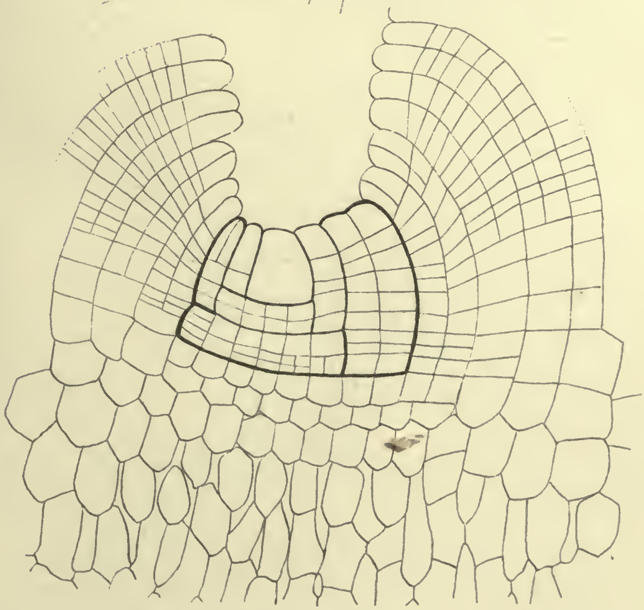

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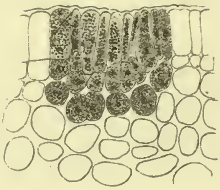
PLATE X.

HELIOTYPE CO., BOSTON.



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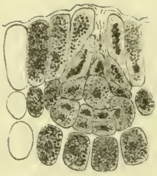

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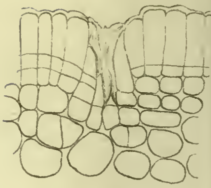

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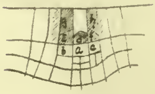

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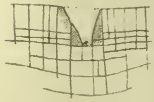

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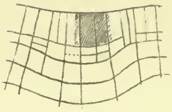

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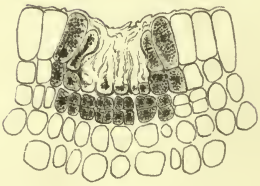

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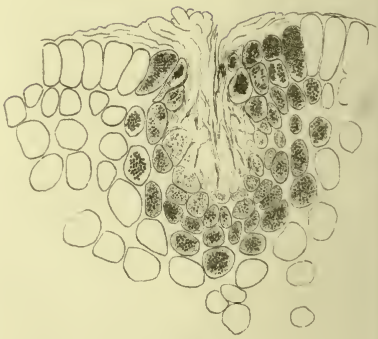

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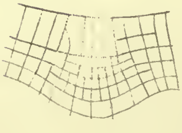

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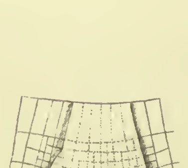

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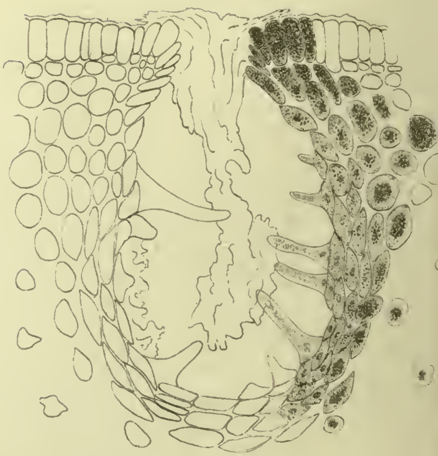

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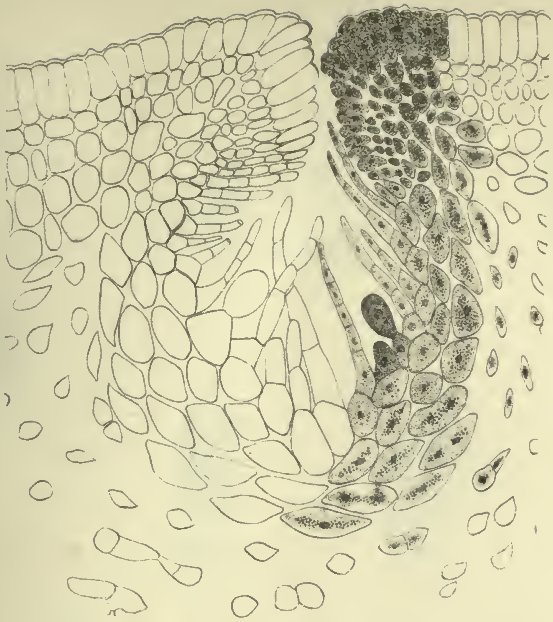

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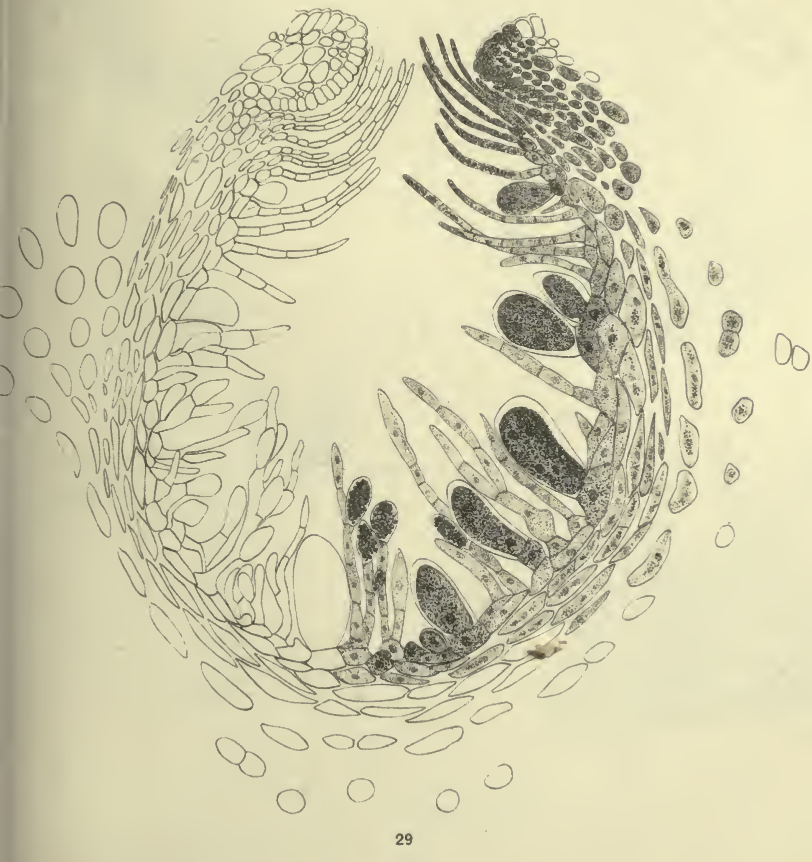

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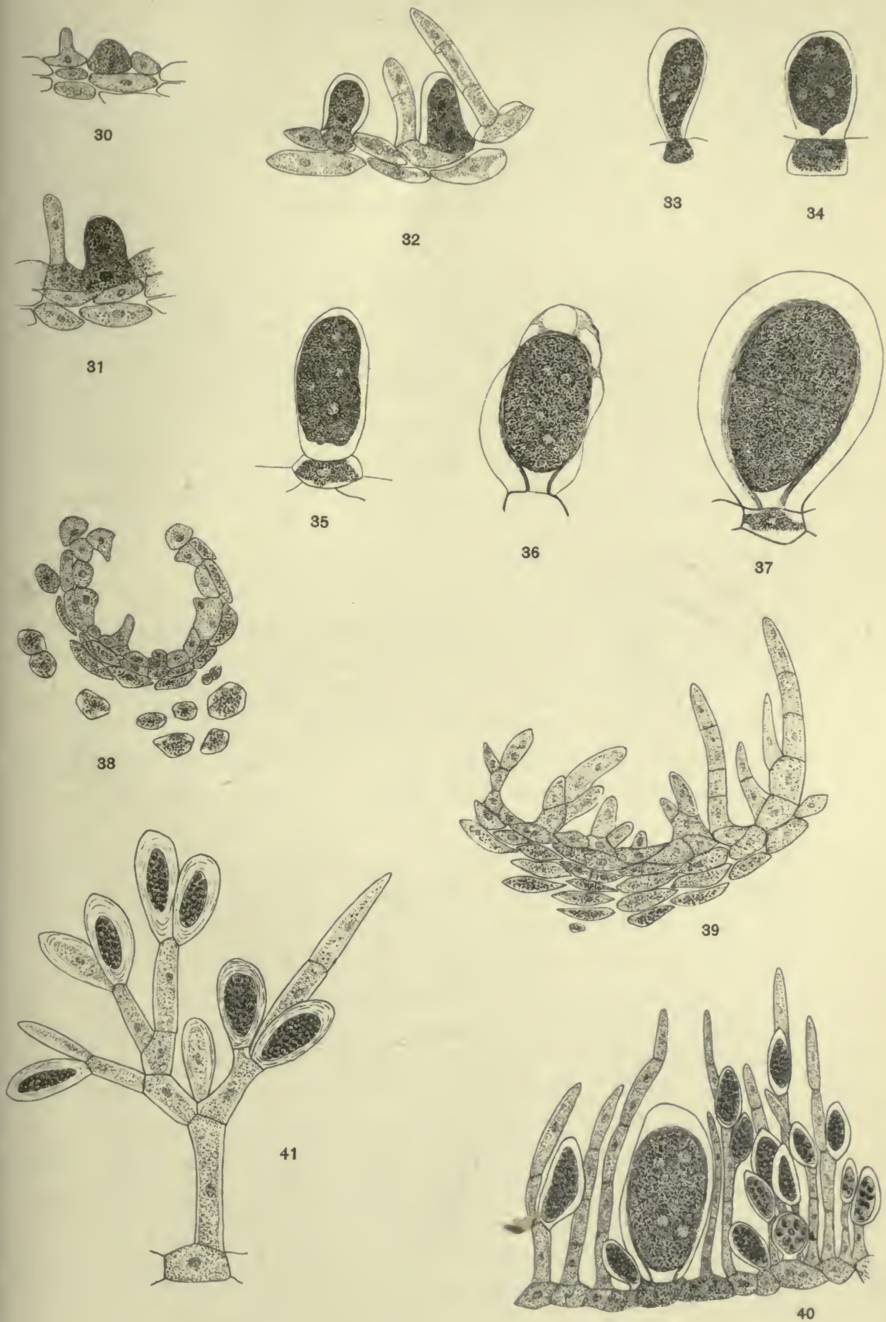

PLATE XII.

HELIOTYPE CO., BOSTON.

IV. PETALONEMA ALATUM IN MINNESOTA.

Daisy S. Hone.

History. — This alga was discovered first in West Scotland by Captain Carmichael, about 1823–1828, and was first figured and described by Dr. Greville as an *Oscillatoria.* It has since been found in various places in Europe, both in the British Isles and on the Continent. In 1849 Harvey found it growing on dripping rocks under Biddle Stairs, Niagara Falls, in America. It was found by the writer near Minneapolis, Minnesota, in October, 1901.

Collection and preservation. — The Minnesota material was collected from the gravel bed of a quiet stream, the outlet of an old tank near the Government Dam works, Minneapolis, on October 12, 1901. It formed a dark chestnut brown stratum. A portion was preserved in a 5-per-cent. formaline solution and the remainder dried for herbarium specimens. The dried material when soaked regains its original form so that it is as good for study as the preserved. However, the formaline material was used in the work recorded in this paper.

Methods. — A small portion of the pickled material was washed in water and then mounted directly in glycerine jelly. If the jelly be raised above the melting point the threads collapse. All the drawings used in this paper were made from a single slide which has been thus preserved.

Staining in toto was tried with several fluids, but without valuable result. After washing the material in water for twenty-four hours it was treated with dilute hydrochloric acid for twenty-four hours and then various staining fluids tried. A dilute solution of Kleinenberg's hæmatoxylin stained the sheath a beautiful blue, leaving the trichome deep green. Aniline safranine stained the trichome red without affecting the sheath. Dahlia colored the trichome a deep blue and slightly affected the sheath. Fuchsin acid stained the whole red. Iodine turned the trichome brown.

Material was also washed with water for twenty-four hours and then passed through the alcohols before staining, but no advantage was gained. The material treated with hydrochloric acid differed only in that it showed a more distinct vacuolated condition, which in the younger active pseudocysts was very apparent. Many of these pseudocysts also showed a single very large granule, but this may also be seen in the normal condition. Nearly all the stained pseudocysts are constricted along the middle region.

Observations.

The dark brown color of the stratum is due to the color of the gelatinous sheaths in which the trichomes are imbedded.

Filaments.—The filaments are not attached, yet the gravel remained clinging to them when they were detached from the bottom of the stream, due no doubt to the gelatinous nature of the sheath. They seemed to lie horizontally and to be without any definite arrangement. They are in general more or less curved. Many of the filaments are without branches, but pseudobranches are not at all uncommon. Branching occurs either near a heterocyst or at a distance from it (see *Figs. 5* and *6*). In the first case there is but one branch, that is, the trichome being broken off at the heterocyst is thrust out as a single thread which soon secretes a new sheath about itself. In the latter condition both the broken ends of the trichome project, so that there are two branches or twin branches.

Sheath.—Harvey's description cannot be improved upon: "When placed under the microscope the filaments present the appearance of a cylindrical central column, containing annulated, olive-colored endochrome and a wide, wing-like border at each side of the column. This border or sheath is obliquely striate, the striæ running in an arch from the margin toward the center, where they become parallel and are then continued longitudinally downward along the medullary column till lost in the density. The margin of the wing is closely crenulate, and in age transversely striate at the crenatures as though jointed. Such is the apparent structure; the real structure seems to be that an annulated central filament is enclosed within a number of compressed, trumpet-mouthed gelatino-membranaceous tubular sheaths, one arising within the other and successively developed as the growth proceeds. These sheaths, thus concentrically arranged, are indicated by arching

longitudinal striæ, and the mouths of the younger sheaths, projecting slightly beyond those of the older, form the crenatures of the margin."

I find the central cylindrical column containing the trichome to be dense and often very thick near the heterocyst (*Fig. 4*), while near the apex of the filament it generally becomes thin and often scarcely traceable (*Fig. 3*). Thus it would seem to be a second sheath within the larger outer one, or it may be merely a very dense interior folding of the sheath proper, intensified near the heterocysts because of the greater rigidity of that portion. The internal striations of the sheath have a beautiful golden or dusky brown feathery appearance. Those farthest within being brown or golden present all shades of brown and yellow as they approach the periphery, where the sheath becomes colorless and transparent. A quite common condition is illustrated in *Fig. 5*, in which a dense old sheath, contracted for a limited distance, after branching expands into the usual form.

Trichome. — The trichome is normally of an olive-green color, cylindrical or somewhat moniliform, separated into distinct pseudocysts or apparently continuous. The apex is often gradually constricted with the tip enlarged. Very often this tip is rose-colored.

Pseudocysts.—The pseudocysts are exceedingly variable in size and shape, this depending upon their age. The younger active pseudocysts are globose in shape, 9–15 mic. wide. When ready to divide they lengthen until they are twice as long as wide (*Fig. 7*). The contents are coarsely granulate. Often a single large granule is seen in each pseudocyst (*Fig. 3*). The older pseudocysts are often rectangular in outline (*Fig. 4, a*). These are sometimes 20 mic. long and 6 mic. wide. They are more finely granular and densely packed. The apical pseudocyst and often three or four below are coarsely granulate and are of a deep pink or red color.

Heterocysts.—The heterocysts are interstitial and sometimes occur at the base of a branch (*Fig. 5*). They are solitary. In shape they are somewhat globose or oblong. In stained material the watery contents take a beautiful color. In size they are slightly larger than a normal pseudocyst.

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Explanation of Plate XIII.

Figure 1. Apex of a filament showing striæ of the sheath, or the "mouths" of the younger sheaths projecting from the older ones. *a*, trichome, × 154.

2. Same view as Fig. 1, but with different focus showing the concentrically arranged striæ with the central portion. *a*, trichome, × 154.

3. Apex of a filament with well-developed trichome about to slip out from end of sheath, × 154.

4. A portion of a normal filament showing heterocysts and hormogone with a very dense central folding of the sheath about the trichome, × 154.

5. A portion of an older filament showing a branch given off at the heterocyst, × 154.

6. A portion of a filament showing four branches not in the neighborhood of a heterocyst, × 154.

7. A trichome showing active division removed from sheath, × 154.

8, 9. Stained trichomes removed from sheath. 8. Mature pseudocysts. 9. Young pseudocysts, × 154.

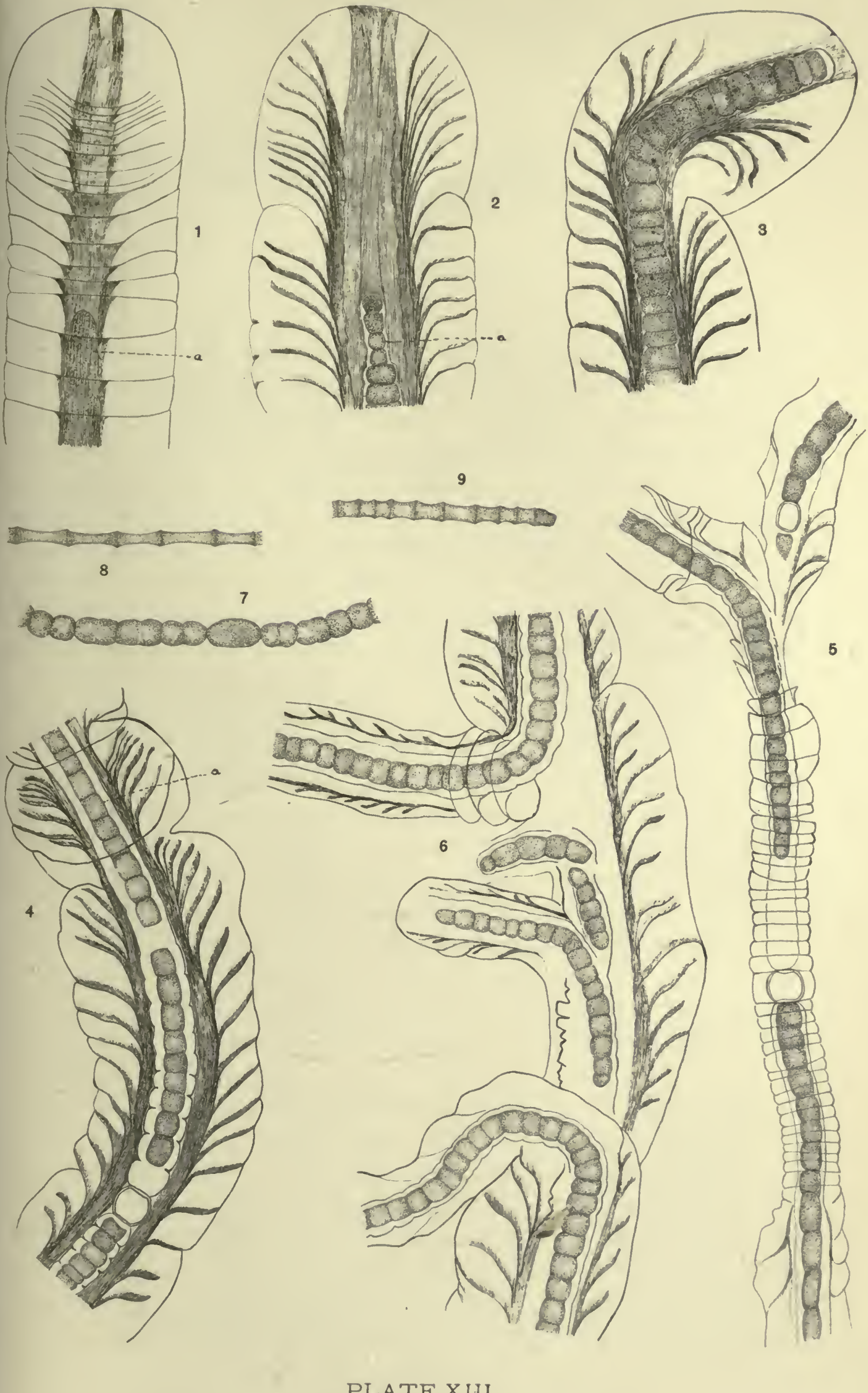

PLATE XIII.

HELIOTYPE CO., BOSTON.

V. OBSERVATIONS UPON SOME ALGÆ WHICH CAUSE "WATER BLOOM."

N. P. B. Nelson.

An endeavor has been made to collect some of the more important known facts concerning "water bloom" as it occurs in Minnesota and neighboring states. It seems quite certain that at least some of the algæ causing this appearance in water supplies are of considerable sanitary importance. It is the object of this paper to give, not a complete and scientific treatise, but a general and practical description of the phenomenon and its causes and effects so far as known. Up to this time there is no record of its occurrence to any great extent in the rivers or lakes supplying drinking water to the inhabitants of cities and towns of the state, but in several instances it has apparently caused the death of cattle and other animals.

Occasionally persons interested in the matter have sent specimens to the Department of Botany at the university, and it would be well if this were more generally done. Such collections with notes accompanying them are of the greatest aid in acquiring a more general and complete knowledge of this kind of vegetation. A small amount of the material, immediately upon being taken out of the water, should be placed in a vial containing a 5-per-cent. solution of formaline. It can then be packed in a small box with cotton and sent at any convenient time. Such a solution of formaline can be purchased for a few cents at any drug store.

History.— The first published record of the occurrence of this "water bloom" in the state of Minnesota was that of J. C. Arthur (1) in 1883. "A very fatal disease among cattle and hogs in Waterville, Le Sueur county," was reported on the 8th of July, 1882. Professor Arthur visited the locality and describes the condition as follows: "On June 28, 1882, after two or three days of pleasant weather, the wind gathered a thick scum of algæ in the little bay (on the north shore of Lake

Tetonka near the house of Mr. L. H. Bullis). Four calves confined in a pasture near the house, with access to no water but that of the lake were seen at noon apparently well, and at 2 P. M. were dead. On July 5, a number of cattle came down the public road to the lake shore, that partly belonged to Mr. Bullis and partly to neighbors. They were noticed between 8 and 9 A.M. and within an hour afterward three were dead, and before noon three more. . . . The two young cattle were examined shortly after death by Dr. E. B. Case and Dr. J. G. Bemis, resident physicians. Nothing seemed to be abnormal except the stomach, which appeared to have been affected by the algæ swallowed by the cattle. . . . The cattle did not appear to suffer pain, but lay down as if enervated and soon expired." The total number of animals thought to have died from the same cause at this time included about twenty head of stock, horses, cattle and hogs.

The scum when examined was found to consist of minute balls each made up of a dense colorless jelly in which was embedded a great number of dark-green, whip-like filaments, lying side by side and radiating from a center. The larger ends were at the center and the attenuated ends extended beyond the jelly. Each filament was made up of a row of pseudocysts enclosed in a sheath and at the basal or inner end was attached a spherical heterocyst. When decaying in masses the plant caused a nauseating odor. The plant was determined by Dr. Farlow to be *Rivularia fluitans* Cohn.

Several weeks later Professor Arthur revisited Lake Tetonka. *Rivularia fluitans* had disappeared, but in its place was another scum-forming alga, intensely green in color, diffused throughout the water and collected by the wind into a scum two or more inches thick along the shore. Under the microscope it appeared to consist of irregular colonies of minute plants. Each colony was a mass of thin, colorless jelly containing many separate oblong blue-geen cells placed some distance apart. This plant is known as *Cœlosphærium kuetzingianum* Naeg. and is not considered injurious. A small quantity of *Anabæna circinalis* (Kuetz.) Rabenh. was also found associated with this plant. Still another " water bloom " species found at this same time and almost as abundant as the *Cœlosphærium* was an alga named *Aphanizomenon flos-aquæ* (Linn.) Ralfs. It consisted of little bundles of thin, delicate filaments.

The next reference to the subject was made in 1889 by Dr. Wm. Trelease in an article, "The Working of the Madison lakes, Wisconsin." He observed that every season a greenish-yellow scum occurred in greater or less quantity on the lakes during the hot part of the summer, after the weather had been calm for a number of days in succession. When but little of the scum-forming substance was present it appeared as fine granules suspended in the water. Under the influence of a gentle breeze, continuing in one direction for some time, these particles were carried to the shore, accumulating to form a slimy scum which quickly putrefied, giving off a disagreeable odor. During the process the color of the mass changed to a decided blue-green, which stained the pebbles, sticks, etc., over which it was smeared. This material consisted mainly of *Clathrocystis aëruginosa* (Kuetz.) Henfr. At different times collections taken from the lakes proved to be, besides the *Clathrocystis*, *Anabæna flos-aquæ* (Lyngb.) Bréb., *A. mendotæ* and *A. circinalis* (Kuetz.) Rabenh.

In August, 1897, Miss Elizabeth H. Foss, a student in the Botanical Department, collected *Glœotrichia pisum*, floating in large quantity on the surface of Lake Minnewaska, Glenwood, Minnesota, and on October 28 of the same year, Miss M. G. Fanning and Mr. H. B. Humphrey found *Anabæna flos-aquæ* in abundance in Cedar lake, Hennepin county, Minnesota.

In November, 1899, Miss M. G. Fanning, then a student in the Botanical Department, began making a study of the St. Paul water supply. Of the "water bloom"-forming algæ she found specimens of *Anabæna flos-aquæ* (Lyngb.) Bréb., and *Cœlosphærium kuetzingianum* Naeg.

In August, 1900, Professor Caswell A. Ballard, of Moorhead Normal School, Moorhead, Minnesota, made a collection of a "water bloom" form from one of the shallow lakes in the depressions of the Fergus Falls moraine. A sample of the material was sent to this department and it was determined to be *Aphanizomenon flos-aquæ* (Linn.) Ralfs. (*Pl. XIV., Fig. 1*).

Professor Ballard's attention was first called to this locality by the report that several cattle in a pasture adjoining the shore of the lake had died, apparently from poisoning. It was observed that the lake was in a peculiar condition, the water colored by a blue-green scum. A zone from twenty to twenty-

five feet wide, from the shore out into the lake, was almost thickened by the presence of a great number of colonies or bundles of this plant. This scum being suspected as the source of danger, a temporary fence was put up to prevent the cattle from drinking out of the lake. After that, none of the cattle died or showed symptoms of being poisoned. In a letter describing the circumstances, Professor Ballard states that he is convinced that the death of the cattle was due to the drinking of the lake water, either because of the poisonous characters of the algæ, or what seems more likely, because of the stagnant condition of the water which made the growth of the algæ possible.

On October 13, 1901, the writer collected some "water bloom" on the shores of Lake Minnetonka at Spring Park. The water here did not seem to be very deep for some distance from the shore. Neither was there a clean sandy bottom in the vicinity. Bulrushes grew abundantly in places and there were present some smaller water plants. The water of the lake was quite fresh and clear.

The algal scum was gathered at a few places along the shore by a gentle land-ward breeze. It had a pale bluish-green color resembling a mixed paint of that color. Microscopic examination showed the scum to be made up of two species of *Anabæna*, *A. flos-aquæ* (Lyngb.) Bréb. (*Pl. XIV., Fig. 3*) and *A. circinalis* (Kuetz.) Rabenh. (*Pl. XIV., Fig. 2*).

On October 24 another collection was made at the same spot. The scum was about the same in quantity, but was of a grayish-brown color, slightly tinged with blue-green. It was more slimy to the touch. It had an odor similar to mouldy grass or hay. Under the microscope it was seen that this difference was probably due to the presence of a much larger number of gonidia or reproductive bodies than had been found in the previous collection.

To the naked eye this scum appeared to be simply a shapeless mass, but examined with the microscope it was found to consist of innumerable filaments, resembling strings of beads. Each of these filaments or trichomes was composed of a number of somewhat spherical pseudocysts, almost uniform in size and shape. Each pseudocyst was filled with a dense, finely granular protoplasm. At intervals in the trichome were seen heterocysts, larger than the pseudocysts, with a more distinct wall and

thin watery contents. The gonidia were still larger, were surrounded by a thick wall and contained numerous granules of different sizes. When floating naturally in the water, each trichome of *Anabæna circinalis* coils itself into a loose spiral — hence its name. The trichome of *A. flos-aquæ*, on the other hand, is somewhat curved but not in a definite way.

These plants in moderate quantities are not supposed to be dangerous, but when they are present in immense numbers in stagnant water they are likely to have an injurious effect.

In 1897 Messrs. D. D. Jackson, Assistant Biologist, and J. W. Ellms, Assistant Chemist of the Massachusetts State Board of Health, made a series of chemical experiments on living plants of *Anabæna circinalis* collected from Ludlow Reservoir, at Springfield. "It is commonly believed by those who have not investigated the subject, that disagreeable odors and tastes in drinking waters are due to the decomposition of organic matter, and are either dangerous or indicative of danger to the public health. Biological investigations already published have sufficed to show that this is not always the case."

The plant under investigation proved to contain an essential oil giving the order of mouldy grass which is characteristic of the genus.

A chemical analysis was also made of the same plant in a state of decay and showed that "the odor of decomposing *Anabæna* is evidently not due, to any extent, to the production of hydrogen sulphide, but to the partial breaking down of highly organized compounds of sulphur and phosphorus. The odor is undoubtedly more offensive on account of the high per cent. of nitrogen present. It is true of the whole organic world that those products which give the most offensive odors of decay are partially decomposed, highly nitrogenous compounds, containing sulphur or phosphorus."

The investigators concluded that the usual cause for disagreeable odors and tastes occurring in potable water is found in the presence of large numbers of certain microscopical organisms which secrete compounds of the nature of essential oils. When the organisms are living these tastes and oders are as harmless as those of fresh vegetables or fish. When decaying, the plant produces the "pig-pen" odor (characteristic of blue-green algæ, Cyanophyceæ) due to the decay of highly nitrogenous organic matter in which partially decomposed sulphur and phosphorus

compounds play the leading part. The sanitary significance of this matter is yet to be determined, but so far analysis indicates that, in large quantities, the effect on general health would be unfavorable.

Summary. — Up to the present time there have been found, in or near the state of Minnesota, seven kinds of blue-green algæ which form "water bloom." They are:

Glœotrichia pisum (AG.) THURET. (*Rivularia fluitans* COHN.)
Cœlosphærium kuetzingianum NAEG.
Aphanizomenon flos-aquæ (LINN.) RALFS.
Clathrocystis aëruginosa (KUETZ.) HENFR.
Anabæna circinalis (KUETZ.) RABENH.
Anabæna flos-aquæ (LYNGB.) BRÉB.
Anabæna mendotæ (?)

In several instances it has been almost conclusively proved that the presence of one or more of these species in drinking water used by stock has caused fatal results.

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EXPLANATION OF PLATE XIV. (IN PART).

Figure 1. A "bundle" of trichomes of *Aphanizomenon flos-aquæ.* Drawn from Professor Ballard's collection, × 700.

2. *Anabæna circinalis.* *a*, pseudocysts; *b*, gonidium; *c*, heterocyst, × 193.

3. *Anabæna flos-aquæ.* *a*, pseudocyst; *b*, gonidium; *c*, heterocyst, × 193.

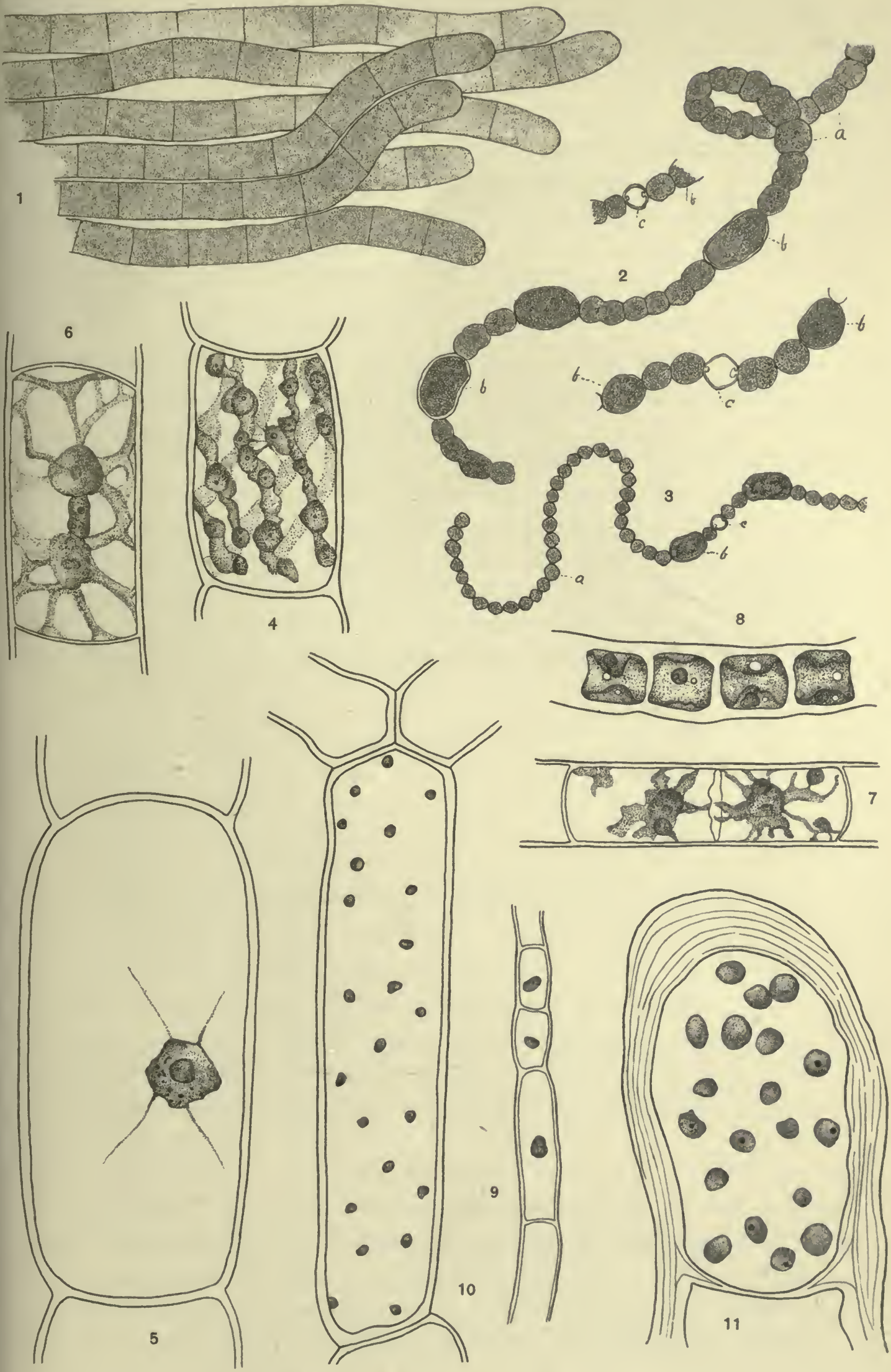

PLATE XIV.

HELIOTYPE CO., BOSTON.

VI. SOME OBSERVATIONS ON THE STAINING OF THE NUCLEI OF FRESH-WATER ALGÆ.

CATHERINE HILLESHEIM.

The material studied comprised several species of the commoner green algæ collected in the stone quarries along the bank of the Mississippi river near the university.

Staining. — The only fixing agents tried were chromic and picric acids. Various stains were used, such as hæmatoxylin, fuchsin, anilin safranin, gentian violet, borax and ammonia carmine. Staining living cells with dahlia was unsuccessful. After the material was stained and thoroughly washed, first in water and then in the alcohols, it was mounted in glycerine jelly or in formaline. The best results were obtained from the following method:

Chromic acid,	24 hours,
Water,	24 "
Alcohol, 10 per cent.,	4 "
Alcohol, 30 per cent.,	4 "
Alcohol, 50 per cent.,	4 "
Borax and ammonia carmine (one half of each),	4 days.
Glycerine and water (5 per cent. solution),	5 minutes.

The slide and cover-glass were then warmed and a small drop of glycerine jelly placed in the center of the slide. When this was melted the stained material was placed in it, the cover-glass laid on and the whole put away to dry. When mounted in formaline the preparation is ringed with Canada balsam to make it air-tight.

CELL STAINING.

Spyrogyra species. — The nucleus readily took on nearly all of the stains mentioned. It was stained pink by the ammonia-borax, carmine, fuchsin and aniline safranin. Hæmatoxylin stained it blue. The nucleus was situated near the center of the cell. It was much varied in shape in different species.

Thus, some were polyhedral, some oval, some spherical and some irregular in form. It also varied in size. The nucleolus stained much more deeply than the nucleus and was spherical in shape. Radiating in all directions from the nucleus are the lighter staining strands of protoplasm which, terminating in the pyrenoids of the chlorophyll bands, suspend the nucleus in the cell.

Zygnema species.— A mixture of ammonia and borax carmine gave the best results in staining in this form. Various stages in nuclear division were clearly brought out. *Pl. XIV., Fig.* 7, shows two daughter nuclei just after the formation of the cell plate. The nucleus is an elongated, oblong, bean-shaped body situated between the two chloroplastids. The nucleolus is generally situated in one end of the nucleus and is spherical in shape. Dahlia was tried but it stained all the contents of the cell without bringing out the nucleus.

Hormiscia zonata (Web. and Mohr) Aresch. — The method of staining was the same as above. The nuclei are somewhat spherical in shape, and occupy different positions in different cells. They lie within the chloroplastid, either at the center or near the wall.

Microspora species. —In addition to the first method, double staining was tried, the material being first stained with anilin safranin and then with gentian violet. This proved to be no more satisfactory than the first method. Stained with hæmatoxylin the nucleolus was brought out much more clearly than in either of the other ways. The method used is as follows:

Chromic acid,	33 hours.
Water,	22 "
Hæmatoxylin,	4 "

The material was then washed in water acidulated with HCl, then placed in a solution of glycerine, and mounted in glycerine jelly. The nucleus in *Microspora* is irregularly spherical or oblong in shape. It usually occupies the center of the cell.

Cœnocyte Staining.

Hydrodictyon reticulatum (Linn.) Lagerh.— The stain used was a mixture of ammonia and borax carmine. The nuclei do not seem to be distributed uniformly throughout the cœnocyte, but most of them occupy a layer or cylinder just within the cell

wall with a very few scattered about in the center. The nuclei are extremely numerous, as many as forty-six being counted in a very young cœnocyte, while in the mature cœnocytes there were many hundred.

Cladophora species.— Both the borax and the ammonia carmine stains were taken very readily by the nuclei of these plants. The nuclei, however, were brought out more clearly when hæmatoxylin was used. In a cœnocyte of one species thirty-eight nuclei were counted. In another species only six could be made out. The nuclei were mostly spherical in shape.

Summary.— The best fixing agent for the algæ studied was chromic acid. The most successful stain was a mixture of borax and ammonia carmine.

Explanation of Plate XIV. (in Part).

All the drawings were made with the camera lucida.

Figure 4. Cell of *Spirogyra*. Length of cell 100 mic., width of cell 50 mic. Diameter of nucleus, 12 mic., × 193.

5. Cell of *Spirogyra*. Shows relative size of nucleus and cell, × 450.

6. Cell of *Zygnema*. Nucleus in resting condition. Diameter of cell 37 mic., length 62 mic. Diameter of nucleus 7 mic., length of nucleus 12 mic., × 450.

7. Cell of *Zygnema*. Daughter nuclei, just after division is complete, × 193.

8. *Hormiscia zonata* (Web. and Mohr.) Aresch. Diameter of cell 20 mic., length 25 mic. Nucleus 5 mic. in diameter, × 450.

9. *Microspora* sp. Diameter of cell 10 mic., length 45 mic. Diameter of nucleus 5 mic., × 450.

10. *Hydrodictyon reticulatum* (Linn.) Lagerh. Diameter of cœnocyte 11 mic., length 66 mic. Diameter of nuclei 1 mic., × 193.

11. *Cladophora* species. Diameter of cœnocyte 63 mic., length 150 mic. Diameter of nucleus 7 mic., × 450.

VII. OBSERVATIONS ON DICTYOSPHÆRIA.

Caroline M. Crosby.

Nomenclature and Classification.

The genus *Dictyosphæria* was founded by Decaisne, *Valonia favulosa* Ag. being chosen as the type. In further investigations by Harvey, Agardh, Kützing and Murray, this systematic position has been accepted by all, near *Valonia* and *Anadyomene*.

The present investigations have been confined to the single species *Dictyosphæria favulosa*, and to material collected in the Hawaiian Islands during the summer of 1900.

These notes will not attempt to discuss the classification which has been so firmly established, but will merely add some details of structure not noticed at length by Murray, and some possible explanations of certain disputed points.

Collection and Preservation of Material.

The material was collected in the following portions of the Hawaiian Islands, May–August, 1900:

1. Kapaa, Island of Kauai, most northern point.
2. Waianae, Island of Oahu, most southern point.

In all cases the material was collected at or near low tide, in shallow water.

The material used was preserved—

1. In 70 per cent. alcohol solution.
2. In 4 per cent. formaline solution.

Investigations were made chiefly on formaline material.

Methods of Preparation.

1. The material prepared with alcohol was allowed to stand twenty minutes or so in gum-arabic solution and then transferred to gum-arabic solution on the freezing chamber. As this medium necessitated transference to glycerine jelly as a mounting medium, the tissue proved too delicate for successful study.

2. Treated most satisfactorily as follows: Formaline material first washed in a fresh 4 per cent. formaline solution was put on freezing chamber in 4 per cent. formaline solution, and transferred directly into permanent mounting medium of 4 per cent. formaline.

The thallus, after repeated attempts with xylol and cedar oil as clearing media, proved too loosely constructed to cut by microtome. The Osterhout freezing method was used with the best results. Sections were cut 15 to 45 μ thick, the first proving best for detailed structure, the second for general outlines of thallus and cells. Hand sectioning proved of value only in a general way.

The staining of *Dictyosphæria*, en masse or in section, proved a difficult matter. The majority of the stains used had little or no value. The loose structure of the thallus could not endure hardening due to alcohol stains — therefore, water stains were used in nearly all cases. Owing to the nature of cell wall and mucilaginous contents the alcohol material was not more satisfactory than the formaline. The following stains gave poor results:

1. Methyl green (saturate solution in H_2O).
2. Fuchsin (saturate solution in 50 per cent. Al).
3. Bismarck brown (saturate solution in H_2O).
4. Borax carmine (almost saturate solution in H_2O).
5. Ammonia carmine (almost saturate solution in H_2O).

Aniline water safranine (*saturate solution* in H_2O) for four minutes' time proved the most satisfactory stain, showing clearly structure of cell wall, needles, haptera, staining the mucilaginous cell contents a yellow-brown.

Sulphuric Acid (very dilute). Twenty-five minutes' time differentiated clearly starch grains of pyrenoid, a dark brown.

Nuclear Stains (alcohol material).

Delafield's Hæmatoxylin five minutes to twenty hours' time stained the walls a bright purple, but only stained cell contents a muddy brown.

Gentian Violet (concentrated solution H_2O), one to three seconds' time. Differentiated pyrenoid centers clearly, but proved too strong for all other structures.

Acid Fuchsin (saturate solution in H_2O), three hours' time, proved the best nuclear stain.

Mounting Media.

1. Glycerine jelly necessitated a second change from gum-arabic.

2. Pure glycerine proved too strong — drew out the stain and clouded when heated.

3. Formaline proved best.

Habitat.—*Dictyosphæria favulosa* occurs in all tropical seas, *i. e.*, Hawaiian Islands, Grenada, St. Thomas, Barbadoes, Ceylon, Mauritius, Red Sea and Philippine Islands.

In all cases it was found firmly attached by rhizoids to flattened coral reefs, as smaller, more rounded plants, or as larger somewhat appressed areas. In shallow water at low tide it grows attached to outer surface of reef or sides of hole in same. It is often mixed with or covered by other algæ.

Gross Anatomy.

A typical older thallus consists of an irregular, flattened, hollow hemisphere, with a single layer of large closely appressed, hexagonal cells, enclosing a hollow center; attached to substratum by central rhizoids on lower surface (*Fig. 1*). The thallus, in early stages somewhat bag-like, later flattens and becomes irregular in shape.

Owing to the plasticity of such an undifferentiated thallus, the size and shape of both surfaces are adapted to the position; expanded if attached to a flat surface; more bag-like in form with wedge-shaped base, if placed between two surfaces. Later the flattening of the upper and lower surfaces, and the irregularity of the upper surface arise as follows:

In younger solid plants the cells are of equal size. Soon those in the center enlarge and through the growth of outer cells become torn and disorganized (*Pl. XV., Fig. 4*). The hollow thus formed enlarges by the same process. The thallus lacks cohesion, gained by interlacing branches in *Struvea*, and is bound together by a membrane; this now splits in all directions causing the thallus to rupture. The membrane, mentioned by Harvey, Kützing and Murray, as extending over the plant body in younger stages, was not found.

The cells divide continuously and replace the torn tissue by a single-celled layer. The resultant form is irregular, expanded, with hollow center, enclosed by upper and lower surface layers, often filled with water (*Pl. XV., Fig. 2*). The outer surface of the cells is tough and membrane-like.

The thallus proved of interest. Murray considers it an aggregate of cells loosely bound by tenacula, comparable to the structure of *Struvea.* Dr. Schmidtz, of Greifswald, considers it an irregularly branched system, equivalent to a congenital branched *Cladophora*, or a collection of *Valonia*-like cells. Wille, in Engler and Prantl, compares it to a "thickly branched system" sent off from a single layer of cells, which coalesce to form the typical layer.

The writer would compare the plant body to a primitive, irregular, sessile, branched system, homologous to the elongated branched system of *Struvea.* Each cell may be considered a sessile detached branch, which coheres by haptera, not by incrustation.

The thallus is of a higher type than *Valonia*, but suggests it in size and structure of cells, and is also a basal type from which still higher branched forms of Valóniaceæ can be derived. The thallus is not encrusted.

Size of thallus.—The specimens collected were small on an average.

	Length.	Width.	Depth.	
Average size,	15 mm.	12 mm.	15 mm.	
Largest size,	35 "	25 "	4 "	(minus rhizoids).
Smallest size,	7 "	5 "	11 "	(with rhizoids).

Color of thallus.—The thalli were of a light transparent green color, sometimes tinged with brown or pink. The rhizoids were vivid green in some cases.

It is possible that the strong green or reddish color is due to the plant being intermixed with such forms as *Halimeda* or some red algæ.

Comparison with other Valoniaceæ.—*Dictyosphæria* might be considered a low type because:

1. Of the primitive, closely appressed branched system.
2. Of the well-developed rhizoids.

Histology.

The five- to six-sided cells on the external surface differ widely in size, some being much enlarged and protruding (*Pl. XV., Fig. 3*). The inner cells and intercellular spaces enlarge toward the center, stretching to abnormal dimensions in older plants.

Cell walls.—The cell walls present a fibrillated appearance, due to a varying number of membrane-like layers (never less

than seven or eight) which compose them. These vary somewhat in number, have an irregular course and protrude to form haptera and needles.

Chemical tests did not show the sphæro-crystals that Murray found in five *Caulerpas*, but not in some Valoniaceæ also tested. The walls are very refractive and present a finely wrinkled appearance on the inner surface, which is not understood.

Inner cell strengthening. — Murray refers to "centripetal membrane point thickenings" in six species of *Caulerpa*. These have been reported only in leaves of *Caulerpa*, rhizoids of *Marchantia* and cells of *Dictyosphæria*. They are merely invaginations of approximately three-fourths of the wall stratifications, into the cavity of the cell at right angles to its depth (*Pl. XV., Fig. 5*).

These needles are formed from the greater portion of the wall and probably softer stratifications. They are refractive, unseptate, colorless, thin-walled and with a waved outline (*Pl. XV., Fig. 7*). The same, of similar structure and development, occur in *Caulerpa*, but differ in being branched many times and interlaced. The present forms are found rarely branched, with either basal (*Pl. XV., Fig. 8*) or apical dichotomy (*Pl. XV., Fig. 9*), yet they can be considered as allied in function, and as a primitive condition of the well-developed cross beams of *Caulerpa*.

Their development occurs as follows: From a minimum (*Pl. XV., Fig. 6*) an increasing number of stratifications invaginate, the inner forming the external wall of the needle. The next stratification passes within this, and this process continues until a varying number have invaginated. Thus the stratifications appear as cross bars, with a lumen between, and a lumen at the base of the needle, the space between the invaginated stratifications and the remaining wall stratifications (*Pl. XV., Figs. 6–9*). The plates explain further details and size. A cross-section proves the theory. The needles occur irregularly over the entire inner surface of the cells of a mature plant, except the upper surface of external cells and the base of rhizoids, where they are absent. The younger plants possess fewer, as there is less strain. From the similarity in structure, origin and branching they can in function be allied to the strengthening structures in *Caulerpa*, which from its large cells needs both the branching interlaced needles and interlaced branches of thallus.

Of Valoniaceæ exposed to like conditions of wind and wave, *Dictyosphæria* needs more firmness. *Valonia* thalli, on account of their form and structure, need no support, and the remaining Valoniaceæ gain sufficient cohesion through interlacing branches.

The presence of the needles may be due to the loose structure of the *Dictyosphæria* thallus, or to the necessity of having an internal balance to the haptera. There is no stimulus to growth from direct contact, as in haptera, and these may arise from strain on older thallus. Whatever the function, it is subsidiary to that of the haptera, as they are less numerous, and chiefly in greater numbers in central cells.

External cell strengthening.—Haptera or intercellular organs of attachment are present in *Udotea*, *Boodlea*, *Microdictyon* and *Spongocladia*, and bind one part of the thallus to another, as in *Struvea*, where they fasten pinna to pinna, or one cell to another as in *Dictyosphæria.* In all cases they bind a thallus of loose structure together.

Origin. — The origin of the haptera is due to the evagination of about one third of the cell wall, similar to the invagination in the case of the needles.

Their primary importance as compared with the needles is perceived, for they are never absent, and no young stages of development are present. They are, however, formed through a similar process, *i. e.*, the evagination of the stratifications. The cross beams, caused by stratifications, are nearer their tips, thus leaving a larger lumen (*Pl. XV.*, *Fig. 10*).

Optical sections near the base appear as dark rings from one to several in number, due to the number of main branches of haptera which are present (*Pl. XV.*, *Fig. 11*).

The haptera are hollow and have no contents.

Development. — The evagination continues until a surface is reached to give the needed stimulus. At this stage the haptere consists of an unbranched tube ending in a closed blunt end *Pl. XV.*, *Fig. 13*). The tube or stalk now begins to lobe dichotomously, and the ends flatten out upon the wall. This continues until a branched circle of lobes is formed, convex and radiating (*Pl. XV.*, *Fig. 10*). The hollow space thus formed between the opposite cell wall and the concave center causes adhesion by sucking (*Pl. XV.*, *Fig. 14*). The base shows from one to three enclosed oval rings, due to the number of main

branches (*Pl. XV., Fig. 11*). The main tubes may develop lobes directly (*Pl. XV., Fig. 11*), or may become branched from one to three times in various directions and levels (*Pl. XV., Figs. 11 and 12*). Each branch then develops (*Pl. XV., Fig. 11*) a separate system of radiating lobes, as seen in cross-section, central view (*Pl. XV., Fig. 12*). As before, the conditions determine size and shape. The haptera are absent from the outer walls of external cells of the thallus, but are abundant elsewhere, and often crowded when developed from the larger cells (*Pl. XV., Fig. 11*). Near the exterior, the closely connected cells cause the haptera to be short-stalked, and after the opposite wall is reached, continued branching occurs over a varying area, limited only by contact with neighboring haptera. In the central cells, longer stalks arise from the separated cells. In the intercellular spaces their length is often much greater, induced by the greater space (*Pl. XV., Fig. 11*). A haptere near the edge of the intercellular space is often two or three times branched, and clasps the surfaces in various directions, to meet the added strain at this position (*Pl. XV., Fig. 11*). The haptera generally extend directly to the opposite cell wall and thus the base from cell 1 alternates with the lobes of cell 2, but they also extend diagonally and at different levels (*Pl. XV., Fig. 11*). The numbers, size of the haptera, length and direction of tubes, number of branches, area of adhesion and position, depend on the distance between the cells.

Rhizoids. — The rhizoids, centrally situated, are elongated, unicellular structures, and are developed from the ventral surface of the thallus. They show little differentiation and correspond to the normal plant cells. They function as primitive holdfasts, attached to the underlying surface of coral, and are thallus cells, enlarged, elongated, irregularly shaped, and, rarely, budded. To strengthen attachment to substratum, haptera, similar to those above described, are formed from the outer edge of rhizoids. These are few in number (*Pl. XV., Fig. 15*). The relation between the strength of the rhizoids and the position of the plant is intimate, their function being aided by secondary structures, the haptera. The color is generally a strong green, rarely reddish.

The cell wall in form and structure is similar to that of thallus cells. In arrangement the rhizoids are scattered or massed together. In size they vary greatly, the longest five mm. by

one mm., the shortest of barely appreciable length by one half mm. Here as elsewhere the organs are but slightly differentiated and vary in size, structure, and number, according to external conditions (*Pl. XV., Figs. 15 and 16*).

Cell Contents.

Endochrome. — The peripheral layer of cell protoplasm consists of dove-tailed polygonal chromatophores, plate-like and distinctly separated by colorless thread-like lines. This single layer of thin wall plates in outer cells of thallus, is dense, stains deeply, and forms a compact unbroken layer. The attachment of this to the cell wall does not appear a close one as the layer becomes easily detached, and floats separately in water (*Pl. XV., Fig. 17*). The layer (*Pl. XV., Fig. 17*) becomes irregularly perforated, less solid and finally (*Pl. XV., Fig. 18*) in inner cells, consists of widely separated chromatophores, joined by numerous thin granular threads. The endochrome does not project into the cell cavity.

In central cells, few chromatophores are present. One kind of chromatophore only can be distinguished, though the size and shape vary somewhat.

Pyrenoid. — Centrally placed within each chromatophore, is an irregularly spherical body, with thicker walls, and stronger refraction (*Pl. XV., Fig. 18*). *Fig. 18* shows in section the thickened wall and hollow center, but does not show the central grain or clefts which are present.

The development of the pyrenoid can be clearly traced. In early stages (*Pl. XV., Fig. 19*) it is more spherical and solid, except for the beginning of a cleft from the outer edge, which cuts to the central grain. This latter enlarges and becomes more irregular in outline, later. More divisions occur, in one plane only, and four to six lobes are formed, all converging to the inner grain, beyond whose outer edge the cleft does not continue. This latter is spherical, thick-walled, refractive, and contains a minute central grain (*Pl. XV., Fig. 20*). Acid fuchsin differentiates the pyrenoid and accompanying starch grains clearly.

Starch grains. — A weakened iodine solution give this characteristic starch reaction. The starch grains show concentric layering and vary in shape from oval and spherical to irregular shapes. They are scattered in older stages near the pyrenoids or throughout the chromatophore (*Pl. XV., Fig. 20*). In

younger plants they are formed against and within the pyrenoid (*Pl. XV., Fig. 19*), from which they seem to have origin, and from which they gradually move, until eventually the majority lie beyond or against the pyrenoid. A small chromatophore generally has from one to three starch grains a larger one five to eight, or even more.

Oil drops. — The large oil drops are scattered irregularly throughout the endochrome, abundant in number. They are differentiated from other protoplasmic structures by large size, lighter color, regular outline, and stronger refraction.

Cell sap. — The cell is entirely filled with a large amount of watery colorless fluid, whose composition was not investigated.

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Explanation to Plate XV.

Figure 1. Form of typical thallus, two fifths natural size.

2. Irregular form of older thallus caused by rupturing of membrane, two fifths natural size.

3. Thallus showing irregularity of upper surface cells, two fifths natural size.

4. Cross section of thallus showing closely appressed outer cells and increasing separation of inner cells, × 168.

5. Cross section showing interior needles of cell, × 45.

6. Cross section showing early development of needle, × 488.

7. Origin of needles, × 488.

8. Basal dichotomous branching of needle, × 488.

9. Apical dichotomous branching of needle, × 488.

10. Origin of haptera; development of two main branches; surface extension of lobes and cross beams, × 212.

11. Diagram of intercellular space showing oval rings representing main branches; wide and narrow expansion of lobes; branching in various directions and at different levels: stalks or main branches of various lengths.

12. Cross section of three main branches, ventral and hollow stalks, × 464.

13. Youngest development of stalk of haptere, × 424.

14. Concave center of haptere from ventral view, × 360.

15. Rhizoid on ventral surface with haptere, × 45.

16. Youngest development of foot on ventral surface, × 45.

17. Peripheral protoplasmic layer of chromatophores, × 35.

18. Widely separated chromatophores of inner cell, × 318.

19. Early development of pyrenoid with central grain and formation of first starch grains, × 760.

20. Older stage of pyrenoid; scattered starch grains and central grain, × 760.

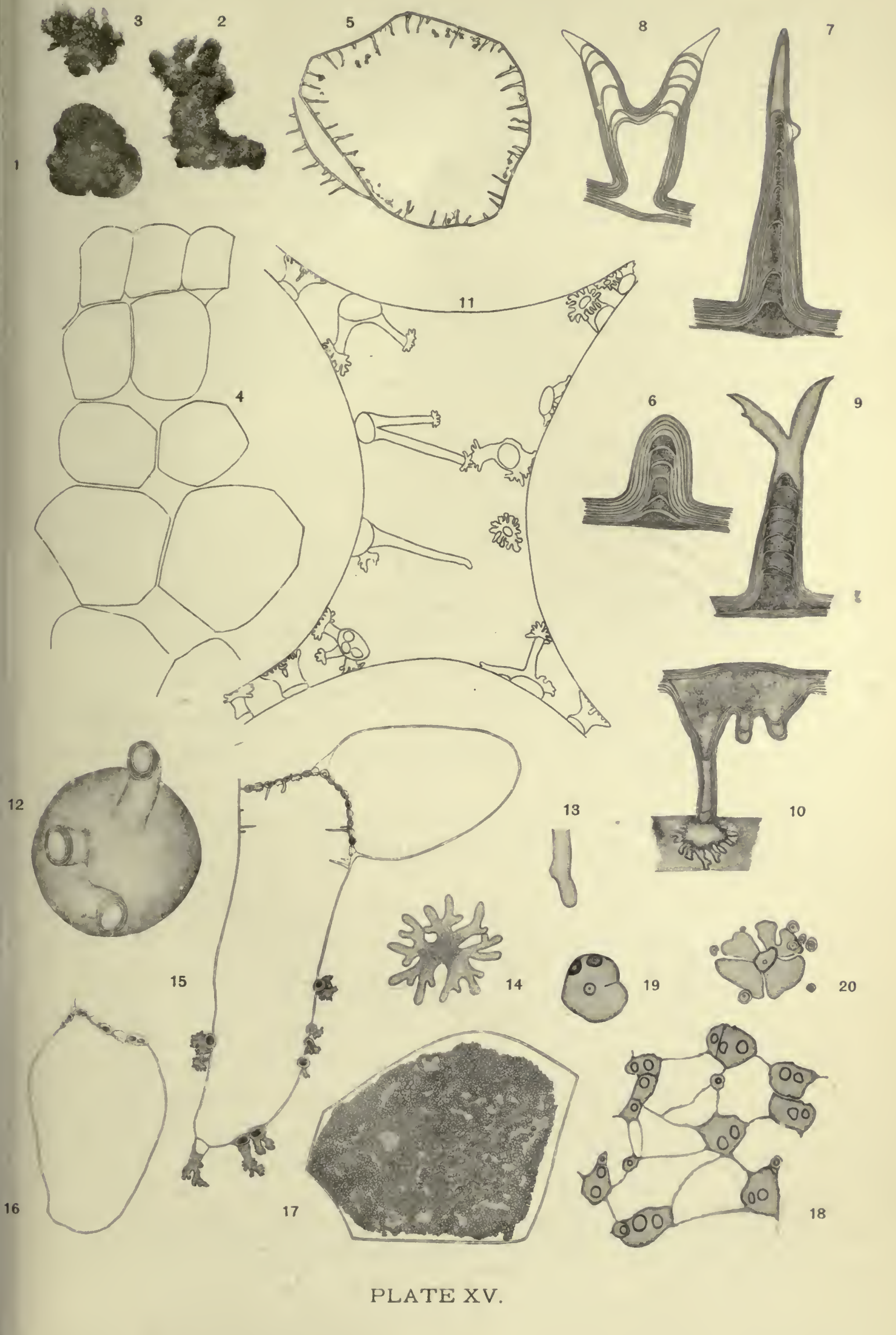

PLATE XV.

HELIOTYPE CO., BOSTON.

VIII. STAPFIA CYLINDRICA IN MINNESOTA.

CHARLES J. BRAND.

The material on which these observations are based was collected by the writer during August, 1901, in the harbor of Grand Marais on the north shore of Lake Superior. It has also been observed at Tobin and Washington harbors on Isle Royale, Michigan.

At Grand Marais the plant was found growing in the water, attached to the smooth diabasic rock, at a depth varying from six inches to eight feet. It was most abundant in a small arm of the harbor which is enclosed on two sides by a reef and on a third by a dock crib. The situation is one that does not ordinarily require any particular ability or adaptation for resisting very violent wave action. However, there are times when the plant is compelled to undergo considerable strain. In the event of a strong wind shoreward the seas break over the outer protecting barrier reef and cause a very strong current from the small arm into the harbor proper and also a fairly violent wave action.

The water in which the collection was made is very fresh and cold, in fact it is the drinking water of the villagers residing about the harbor.

It seemed at first that the plant was simply a species of *Tetraspora*, but a careful examination leaves no doubt but that it belongs to the genus *Stapfia*, established by Chodat in 1897.

In the present form the position of the thallus in its usual condition of growth is always upright. The mode of attachment is by means of a distinct holdfast. Just above the holdfast there is a short attenuated area, beyond which the thallus assumes its ordinary diameter. This feature can readily be observed by reference to the figure of the entire plant (*Pl. XVI.*, *Figs. 1, 2, 3*).

An examination of the thallus with the dissecting microscope or even without a lens, reveals a much wrinkled and folded sur-

face. The color is uniformly a very dilute green. The gelatinous thallus is firm and slippery.

A species of *Bulbochæte* was found very commonly growing as an epiphyte on the plant, being attached by a sort of subspherical cell imbedded in the gelatinous mass of the *Stapfia* thallus. Diatoms and desmids were also found in great numbers in the interior of the thallus.

The material used for this study was preserved in 2 per cent. formaline and as a consequence was rather unfavorable for cytological investigation.

After washing the material for about thirty-six hours in water, it was passed through the usual series of alcohols and xylols into paraffine. The plants were permitted to remain in each for a short time only, as they were very prone to grow hard and brittle, especially if left too long in the higher per cents. of alcohol or in xylol. The material was suitably imbedded for securing both longitudinal and transverse sections. The sections were mounted in series and cleared in the usual manner.

After trying numerous stains, it was found that gentian violet and Bismarck brown were the most useful. A concentrated aqueous solution of the Bismarck brown was used and the mounted sections were allowed to remain in this for about two hours. Only a 2 per cent. aqueous solution of the gentian violet was used and the slides were left in the stain for about three minutes. Canada balsam was used as the mounting medium.

The cross-sections disclosed some very interesting foldings of the gelatinous membrane, which cause the perforate appearance seen in the diagrammatic sketch of the transverse section (*Pl. XVI., Fig. 4*) and also in the longitudinal section (*Pl. XVI., Fig. 6*). The cross-section reveals no particular method in the grouping of the cells in the gelatinous structure. The cells are distributed in a single peripheral layer. They appear to be in groups of two and four for the most part, but also in threes and singly in the older thalli.

The longitudinal section (*Pl. XVI., Fig. 7*) does not differ in essential features from the transverse, although the folds are much more clearly distinguishable. This cut also shows clearly the sort of alveolar structure of the interior of the thallus, of which I have been unable to find any mention in the descriptions of either *Stapfia* or *Tetraspora*. This may be the adapta-

tion by which buoyancy is secured and the ordinary upright position of the thallus is made possible. The structure may be produced by the degeneration of the gelatin of the interior.

The plant very strongly resembles *Enteromorpha intestinalis* of marine waters in its pale green color, subtubular thallus, variability in size and attenuate base.

The plants of Nordstedt, Wittrock and Lagerheim, no. 1362, distributed as *Tetraspora cylindrica* (Wahlenb.) Ag. f. *enteromorphoides* Lagerh. nov. form, which, according to Chodat, no doubt belongs to the genus *Stapfia*, resembles the Lake Superior form considerably, though there are some dissimilarities as may be seen by a comparison of the two. The thallus of the former is fistulose, while that of the Lake Superior plant is subfistulose or alveolar. They agree in that both are verrucose, but disagree in that the former may sometimes be ramose, the latter never. The former is described by Lagerheim as "fragili," while the latter is firm and quite tough. They differ also in color, the former being of a much darker green. The Lake Superior form, however, is darker in color in quiet, less fresh, water. The former has rather short thalli in comparison to the diameter, while the Lake Superior plant has a thallus long and of relatively small diameter. The former is much like the larger of the type specimens distributed by Stapf as *Stapfia cylindrica*, while the latter resemble very much the slender and relatively much longer specimens of the same distribution. There is also the great difference in habitat, the one being found in the largest of the fresh-water lakes and the other in a swift-flowing alpine stream of northern Norway.

Exteriorly the plant resembles most strongly the specimens distributed by Rabenhorst as no. 2244, *Tetraspora cylindrica*. There is, however, a greater variance in length. The shortest of my specimens are about as long as the longest of Rabenhorst, while the longest are nearly as long as Wittrock and Nordstedt's *Tetraspora cylindrica* forma *rivularis*. The former were collected on rocks in Lake Wettern, near Jonköping, Sweden, by Nordstedt, and the latter were also collected by him near Kongsvold, Norway, in the river Driva.

The Lake Superior form may be described as follows:

Thallus 2–5 mm. in diameter, 6 cm. to 3 dec. in length, dilute green in color, erect, gelatinous, cylindrical, subfistulose, sometimes rugose-verrucose, unbranched, firm, rather tough,

clavate at distal end, suddenly attenuate at the base into a brief stipe; holdfast disc-shaped; cells spherical, solitary or in groups of two, four or rarely three, 4–16 mic. in diameter. Attached to rocks at lake bottom.

Bibliography.

Chodat, R. Bull. l'Herb. Boiss. 5: 939. *pl. 23.* 1897.
Chodat, R. Algues vertes de la Suisse, 112. *pl. 49, 52.* 1902.

Explanation of Plate XVI. (in Part).

Figures 1, 2, 3. Plants one half natural size.
4. Diagram of transverse section.
5. Cross-section of thallus, × 235.
6. Longitudinal section of thallus showing fold, × 120.
7. Longitudinal section of thallus, × 235.

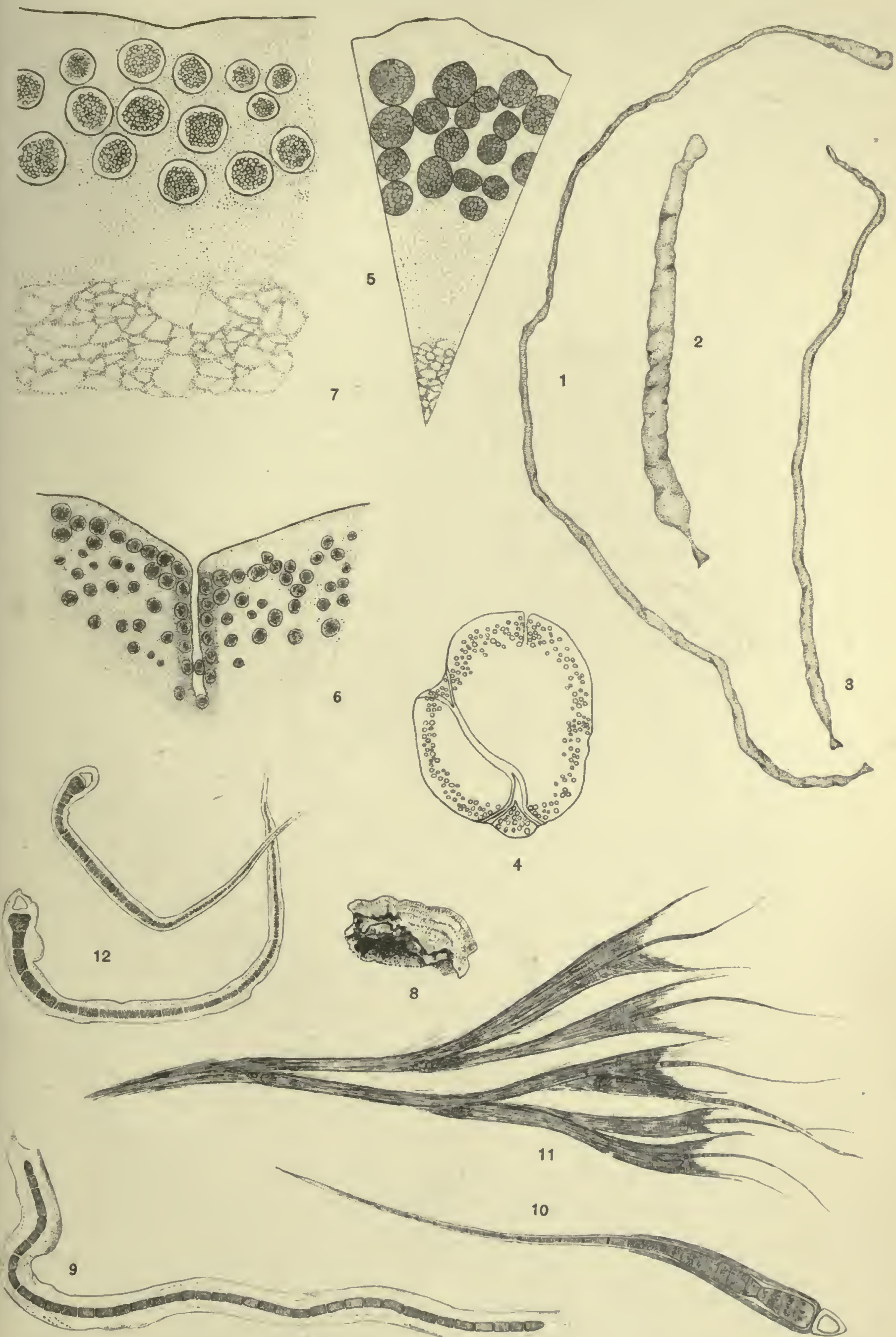

PLATE XVI.

HELIOTYPE CO., BOSTON.

IX. OBSERVATIONS ON SOME CALCAREOUS PEBBLES.

Chalmer Powell.

The first account of pebbles formed by algæ in the United States is given by Dr. George Murray (1). The pebbles examined by him were found in eight feet of water on the sandy bottom of a Michigan pond separated from Lake Michigan by a sand-bar. The specimens varied in size from one to three and a half inches in diameter, were hollow and showed a stratified or concentrically zoned structure. Upon decalcification they were found to be composed of a densely interwoven mass of filaments. The predominating kind was a species of *Schizothrix*, *S. fasciculata* Gomont. There were also filaments of *Stigonema* and *Dichothrix* and a large number and variety of diatoms.

Mr. Thiselton-Dyer (2) refers to the occurrence of pebbles on the bottom of Lough Belvedere, near Mullingar, which were "of all sizes up to that of a filbert." The bulk of the algal mass consisted of a *Rivularia*.

The first mention of calcareous pebbles in American literature was made by Professor Conway MacMillan (3), who states that although he had "not yet found any of these algal pebbles in lakes of Minnesota, it is probable that they occur." This prediction was realized in June, 1901.

In describing pebbles found along the shore of Littlefield lake, Michigan, Mr. Charles A. Davis (4) states that they are "the result of the development and growth of an alga, *Zonotrichia*, or a nearly related species. The vegetable origin of these pebbles would not be suspected until one recently taken from the water is broken open, when it is found to show a radial structure of bluish-green lines." In a preceding article the same author (5) describes a blue-green alga concerned in the formation of marl, which had been determined to be a species of *Zonotrichia* or some closely related genus. "The plant grows in relatively long filaments formed by cells grow-

ing end to end, and as they grow the filaments become encased in calcareous sheaths. The feature of the plant which makes it important in this discussion, however, is its habit of growing in masses or colonies. The colony seems to start at some point of attachment or on some object like a shell and to grow outward radially in all directions, each filament independent of all others and all precipitating calcium carbonate tubules. The tubules are strong enough to serve as points of attachment for other plants, and these add themselves to the little spheroid and entangle particles of solid matter, which in turn are held by new growths of the lime-precipitating *Zonotrichia* and thus a pebble of greater or less size is formed, which, to the casual observer, is in no wise different from an ordinary water-rounded pebble. These algal calcareous pebbles show both radial and concentric structure and might well be taken for concretions formed by rolling some sticky substance over and over in the wet marl on which they occur, but for the fact that a considerable number of them show eccentric radial arrangement and that the shells of accretion are likewise much thicker on one side than on the other, and finally, because the side which rests on the bottom is usually imperfect and much less compact than the others. The pebbles are characteristically ellipsoidal in shape. The radial lines, noticeable in cross-sections of the pebbles, are considered by the writer to be formed by the growth of the filaments, while the concentric lines probably represent periods of growth of the plants, either seasonal or annual." Other forms than the *Zonotrichia* were found in the pebbles.

In June, 1901, Messrs. Freeman and Lyon, of the Botanical Department of the University of Minnesota, found some calcareous pebbles in Clearwater lake, Wright county, Minnesota. This lake covers an area of about four square miles and is really two lakes connected by a narrow strait. The pebbles were collected from the southern arm. They were found lying in from four to ten feet of clear water on sand-bars, which rose abruptly towards the surface and at their edges sloped almost perpendicularly into deep water.

These pebbles range in size from that of a small hickory nut to two inches in diameter. Most of them are flattened, and, though comparatively smooth in some cases, are often rough, coagulated and wave-worn. All are more or less hollow. In section they have a distinctly stratified appearance. The theory

of Mr. Davis given above is the most probable one for their formation.

A study was made of the pebbles which had been preserved in 5 per cent. formalin. Sections cut with a sharp scalpel were placed in a weak solution of hydrochloric acid until decalcified, after which they were immediately mounted in glycerine jelly. The pebbles were found to be composed of a densely interwoven mass of filaments of which the most common type was those of *Schizothrix fasciculata* Gomont. The trichomes were 1.4 to 3 mic. broad. The pseudocysts were equal in length to diameter of trichome or twice as long, 1.2 to 3.5 mic. long. A species of *Calothrix*, two species of *Cosmarium*, a *Nostoc* and numerous diatoms were also present in the pebbles.

In June, 1901, Miss Daisy Hone collected some small pebbles at Point Douglas, Minn., on a steep bluff side overlooking the Mississippi river. Being high above the water they were not supplied with moisture and seemed perfectly dry at the time of collection. These pebbles had an outside layer of calcareous material, which, when decalcified, showed the presence of an alga, a species of *Scytonema*.

Bibliography.

1. **Murray, G.** Phyc. Mem. 74–77. 1895.
2. **Thiselton-Dyer, W. T.** Ann. Bot. 5: 225. 1890–91.
3. **MacMillan, C.** Minn. Plant Life, 41. 1899.
4. **Davis, C. A.** Journ. Geol. 8: 502. 1900.
5. **Davis, C. A.** Journ. Geol. 8: 495. 1900.

Explanation of Plates.

Plate XVI. (in Part).

Figure 8. A section of a pebble showing stratified layers, nat. size.
9. A filament of *Schizothrix*, × 600.
10. *Calothrix* sp. Detail of an older filament, × 335.
11. Same. Portion of thallus showing method of branching, × 64.
12. Same. Young free filaments, × 200.

Plate XVII.

Figures 1–5. Calcareous pebbles, one half natural size.
1. Pebble showing smooth surface.
2. One showing a rougher surface.
3. One showing a still rougher and more porous surface, probably wave-worn.
4 and 5. Hollow interiors of two pebbles are shown.

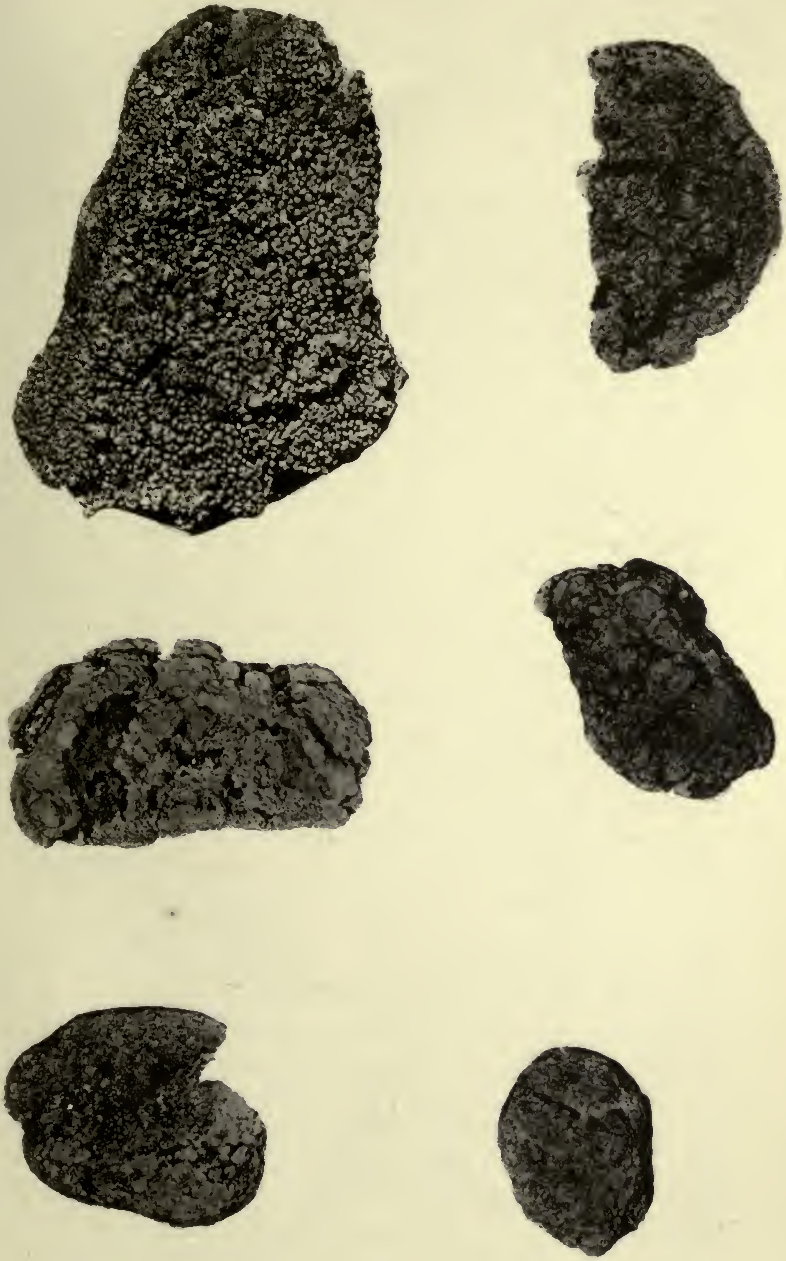

PLATE XVII.

HELIOTYPE CO., BOSTON.

X. NITELLA BATRACHOSPERMA IN MINNESOTA.

GENE LILLEY.

The first record of *Nitella batrachosperma* was made in 1833 by Reichenbach who called it *Chara batrachosperma.* In 1847 A. Braun (1) placed it with the Nitellæ.

The plant is quite widely distributed in Europe. Migula states that it has been reported from Germany, Switzerland, Sweden, Finland, France, Austria, Italy, Spain and that also it has been reported from Australia and North America. During the summer of 1898 A. J. Pieters, Assistant Botanist of the Department of Agriculture, collected *Nitella batrachosperma* at East Harbor, Ohio. He describes the habitat as follows: "At East Harbor there is a wide stretch of swamp intersected by channels which open into the lake by one deep and narrow channel protected from severe wave action by a sand-bar. . . A short distance from the entrance, the channel divides, one branch going east, the other west. . . . Just where the channel turns toward the east is a sandy beach covered with two feet or less of water, and here grow several species of Characeæ, which are more abundant here than elsewhere in the swamp. *Nitella tenuissima* and *N. batrachosperma* grow in about one foot of water with their branches spread out flat on the sand."

Nitella batrachosperma was collected in Minnesota by the writer in August, 1901, at Pike lake, a small shallow lake twelve miles west of Duluth. The plants grew on a sandy beach where the water was from three to six inches deep. The east end of the lake is the only part where the beach is sandy, and although the shore around the lake was examined carefully it was only at this one place that the plants were seen. *Chara coronata* Ziz. was found with *N. batrachosperma. N. tenuissima* Desv., which is usually reported with *N. batrachosperma,* was not found at this place. The collection was made in the morning when the sun's rays struck the water at such an angle as to light up the sandy bottom, so that the plant could be easily distinguished from *Chara coronata.* The previous afternoon

the plant had been overlooked as its dirty brown or gray color and its low prostrate habit gave it the appearance of débris. Very few plants were found.

Description of plant. — *Nitella batrachosperma* is of a dirty brownish-green color, very small, from 1.8 cm. to 3 cm. high. Most of the plants examined were 2 cm. high. There are from two to four main branches springing from the first node. The branches measure .5 mm. in diameter and from 4–7 mm. to the first whorl of leaves. This whorl of leaves consists of six to eight sterile leaves, having two divisions. The first division or main ray is from 55 to 67.5 mic. wide and 685.5 to 750 mic. long. The leaflets are about the same length and are two-celled, the basal cell being very long, the end cell short and sharp-pointed. The lower sterile leaves are loose and spreading and stand at nearly right angles to the main branch. At the tip of the branch the leaves are thick and compressed, giving a bushy-like appearance to the plant. At the apex both sterile and fertile leaves have from two to three divisions. In a fertile leaf, having three leaflets divided and three undivided, the main ray is 50 mic. broad and 312 mic. long. In a sterile leaf with three leaflets divided and three undivided the diameter of the main ray is 62.5 mic. and the length 312.5 mic. In a sterile leaf having three divisions throughout, the diameter is 80 mic. and the length 250 mic., showing little difference in size of fertile and sterile leaves. The fertile leaves are all borne at the tip of the branch and but lew leaves at the tip are sterile.

Rhizoids. — Rhizoids arise from the first and second nodes of the plant. The rhizoids from the first node are much larger than those from the second, being 125 mic. in diameter, while those from the upper are about 62 mic. wide. The rhizoids have long cells and abut upon one another in the characteristic "stocking-foot" manner of the Characeæ.

Reproduction. — *Nitella batrachosperma* is monœcious. The antheridia and oögonia are usually borne on the same leaf, though not always. Many of the leaves bear only antheridia, few bear only oögonia. The organs can be distinguished only by careful examination as they are minute and the color, a yellowish-brown, differs but little from the color of the plant.

Antheridium. — The antheridia are borne terminally upon the first segment of the leaf. The second and third divisions do not bear antheridia or oögonia. The development of the an-

theridium is very similar to that of *Nitella flexilis.* It can be distinguished very early in the growing point by its position and size. It is at first a large spherical cell having a large nucleus. The first division after the stalk cell is cut off is vertical (*Pl. XVIII., Fig. 10*). The second division is transverse (*Pl. XVIII., Fig. 11*). The unfolding of the walls is seen in the sixteen-celled stage (*Pl. XVIII., Fig. 12*). The shields in the mature state are hyaline and contain few chlorophyll bodies and little coloring matter, so that the contents can be easily made out in optical section. Mature antheridia are 135 by 210 mic. in diameter.

Oögonium. — The oögonium arises at the base of the antheridium and takes the place of a leaflet. But one oögonium is borne on a leaf. All stages of development can be found on the same plant. Two "Wendung-zellen" were observed in *N. batrachosperma* (*Pl. XVIII., Figs. 7 and 8*). The filaments surrounding the egg and crown cells are colorless and hyaline. The oösperm is almost spherical (270 by 300 mic.). It is of a rich, golden brown color.

Bibliography.

Migula, W. Die Characeen, in Rabenhorst, Kryptogamen Flora, 184. 1897.

Pieters, A. J. The Plants of western Lake Erie. U. S. Fish Comm. Bull. 64, 78. 1901.

Description of Plate XVIII.

Figure 1. Photograph of *Nitella batrachosperma.* Twice natural size.

2. Rhizoid showing "stocking-foot" cells with branches, × 300.

3. Outline drawing of fertile leaf showing tip of first division bearing antheridium and oögonium, × 300.

4. Apex of leaf bearing antheridium, oögonium and leaflet, × 150.

5. Apical cell of branch showing three nodal cells, × 300.

6. Apical cell of branch showing nodal cells and last internodal cell, × 300.

7. Young oögonium showing first Wendung-zelle and first division of crown cells, × 300.

8. Young oögonium showing two Wendung-zellen and two cells of the crown, × 300.

9. Membrane of oögonium, much magnified.

10. Young antheridium showing stalk cell cut off and first division of antheridium, × 300.

11. Young antheridium in four-celled stage, × 300.

12. Young antheridium in sixteen-celled stage, with young leaflets, × 300.

13. Young antheridium with shields, × 300.

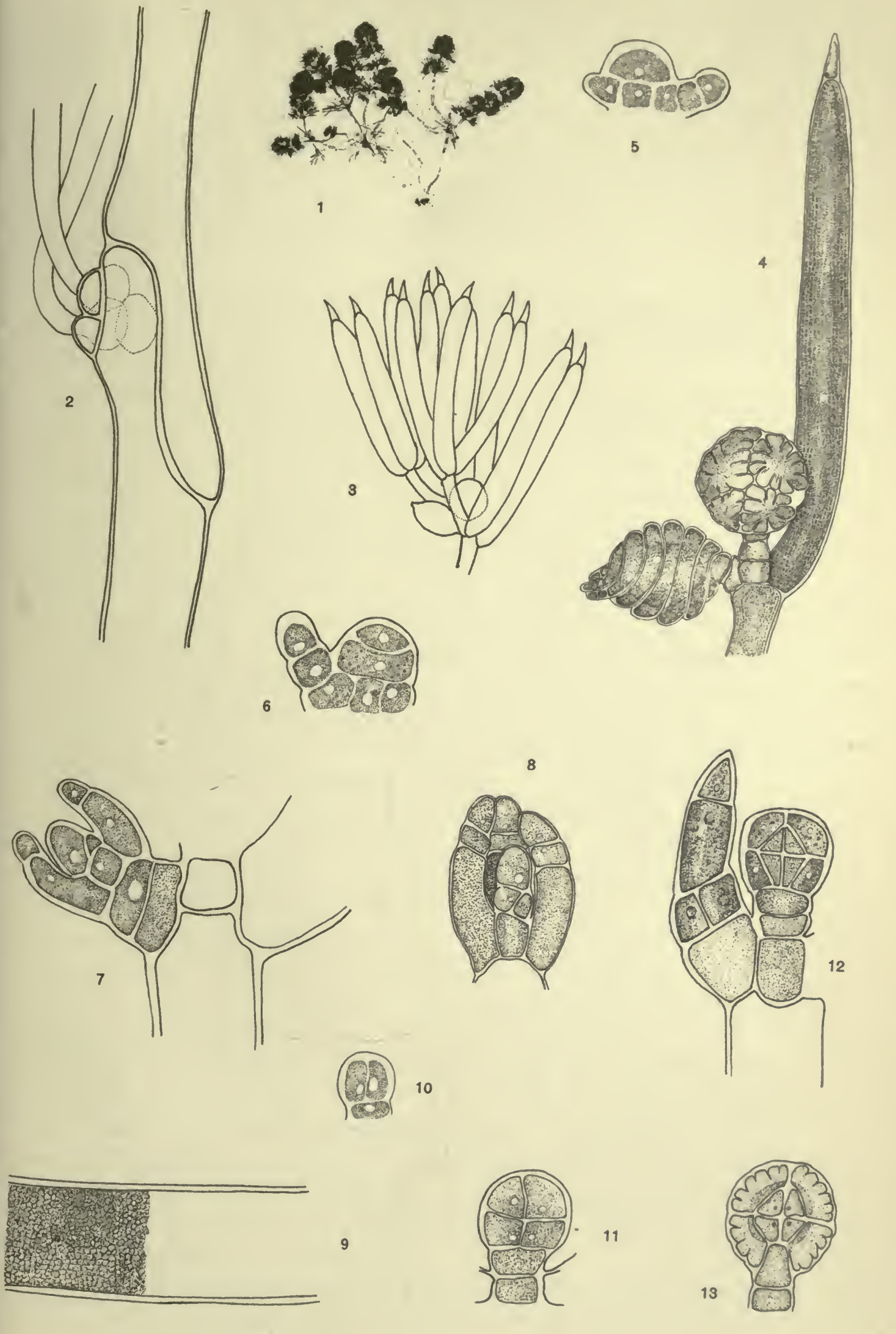

PLATE XVIII.

HELIOTYPE CO., BOSTON.

XI. CATALOG OF MINNESOTA GRASSES.

W. A. Wheeler.

The following catalog of the grasses of Minnesota is a partial report of the work done on the Minnesota Botanical Survey during 1902.

Upham's catalog of the Flora of Minnesota, published in 1884, lists one hundred and thirty-nine species and varieties as occurring within the limits of the state. In the Metaspermæ of the Minnesota Valley, published in 1892, Professor Conway MacMillan lists ninety species and varieties indigenous to the drainage basin of the Minnesota river. Other local reports contain lists of Minnesota grasses. Most of these lists, however, have been incorporated in the two reports just cited.

This catalog of one hundred and seventy-eight species and varieties is based mainly upon a redetermination by the writer of all the specimens of Minnesota grasses in the Herbarium of the University of Minnesota. One hundred and thirty-eight species and varieties have been so determined. The reports of the remaining forty species listed have been taken from previous publications without examination of specimens. Seven of these have been cancelled by corrections in the determination of the specimens cited. Probably others of the forty so listed have also been reported without sufficient evidence or upon incorrect determination, but the specimens are not at hand for comparison. These have, however, all been listed, and are accompanied by notes stating upon what the report is based.

Twenty-four species not previously reported from the state are listed in this catalog. Some of these were determined from lately-published descriptions, without specimens for comparison, and are therefore somewhat doubtful. This refers especially to the species of *Panicum*. Some specimens of *Elymus* remain undetermined because of insufficient material of recently published species for comparison.

Synonyms are given where confusion might arise in a comparison with other Minnesota reports. Herbarium specimens

are cited only when the species is poorly represented by specimens in the Herbarium of the University.

Andropogon scoparius MICHX. Fl. Bor. Am. 1: 57. 1803. Beard grass.

Common in dry soil throughout.

Herb.: Specimens from all parts of the state.

Andropogon furcatus MUHL. Willd. Sp. Pl. 4: 919. 1806. Blue stem.

Andropogon provincialis furcatus HACK. in DC. Mon. Phan. 6: 442. 1889.

Common in dry soil throughout.

Herb.: Specimens from all parts of the state.

Sorghastrum avenaceum (MICHX.) Nash, in Britton, Man. Fl. U. S. and Can. 71. 1901. Indian grass.

Chrysopogon avenaceus BENTH. Journ. Linn. Soc. 19: 73. 1881.

Common throughout.

Herb.: Numerous specimens.

Syntherisma linearis (KROCK.) NASH, Bull. Torr. Club, 22: 420. 1895. Small crab-grass.

Panicum glabrum GAND. Agrost. 1: 22. 1811.

Waste and cultivated ground throughout.

Herb.: Ballard 1168, Goodhue county; Aiton, Hennepin county; Frost 380, Kandiyohi county; Sandberg, Hennepin county; Campbell 179, St. Cloud.

Syntherisma sanguinalis (L.) NASH, Bull. Torr. Club, 22: 42. 1895. Large crab-grass.

Panicum sanguinale L. Sp. Pl. 57. 1753.

Waste and cultivated ground.

Herb.: Aiton, Minneapolis; Wheeler, Houston county.

Echinochloa crus-galli (L.) BEAUV. l. c. Barnyard grass.

Panicum crus-galli L. Sp. Pl. 56. 1753.

Common as a weed throughout.

Herb.: Numerous specimens.

Echinochloa walteri (PURSH) NASH, in Britton, Man. Fl. U. S. and Can. 78. 1901. Cockspur-grass.

Panicum crus-galli hispidum TORR. Fl. N. Y. 2: 424. 1843.

Panicum walteri PURSH, Fl. Am. Sept. 1: 66. 1814

In similar locations to *E. crus-galli* (L.) Beauv., but not so common.

Herb.: A. M. Johnson, Hennepin county; Wheeler, Forest Lake; Aiton, Lake Waseca.

Panicum capillare L. Sp. Pl. 58. 1753. Witch grass.

Common in dry soil throughout.

Herb.: Numerous specimens.

Panicum cognatum Schultes, R. & S. Syst. **2**: 235. Diffuse panicum.

Panicum autumnale Bosc. Spreng. Syst. **1**: 320. 1825.

Reported from Minnesota in Upham's catalog, but not represented by specimens in the University herbarium.

Panicum virgatum L. Sp. Pl. 59. 1753. Tall smooth panicum.

Common throughout.

Herb.: Numerous specimens.

Panicum agrostoides Spreng. Pugill. **2**: 4. Agrostis-like panicum.

Reported from Minnesota in Upham's catalog and in MacMillan's Metaspermæ of the Minnesota Valley, but not represented by specimens in the University herbarium.

Panicum depauperatum Muhl. Gram. 112. 1817. Starved panicum.

Reported from Minnesota by Upham and MacMillan and probably occurs here. Perhaps confused with the two following species.

Panicum linearifolium Scribn. in Br. & Br. Illus. Fl. App. **3**: 500. 1898. Narrow-leaved panicum.

Dry soil, south.

The determination of the specimens cited under this and the two following species were made entirely from descriptions without comparison with authentic determinations and are therefore somewhat doubtful.

Herb.: Rosendahl 259, Spring Grove; Holzinger, Winona.

Panicum perlongum Nash, Bull. Torr. Club, **26**: 575. 1899. Elongated panicum.

Dry soil, south.

Herb.: Sheldon, Mille Lacs Indian Reservation, 2686, Brainerd; Ballard 1010, Nicollet county; Sandberg, Hennepin county; Wheeler 1192, Winona.

Panicum werneri SCRIBN. in Br. & Br. Illus. Fl. App. **3**: 501. 1898. Werner's panicum.

Not previously reported from Minnesota.

Herb.: Oestlund, Hennepin county (?).

Panicum angustifolium ELL. Bot. S. C. & Ga. **1**: 129. 1817. Taller narrow-leaved panicum.

Panicum consanguineum S. WATS. in A. Gray, Man. Ed. 6, 633, in part. 1890.

Reported from Minnesota in Upham's catalog and MacMillan's Metaspermæ of the Minnesota Valley, but not represented by specimens in the University herbarium.

Panicum dichotomum L. Sp. Pl. 58. 1753. Forked panicum.

The previous reports of this probably refer to some other species, as this species is not known to occur in our range.

Panicum boreale NASH, Bull. Torr. Club, **22**: 421. 1895. Northern panicum.

In moist soil. Not previously reported from Minnesota.

Herb.: Sandberg, Hennepin county.

Panicum implicatum SCRIBN. in Br. & Br. Illus. Fl. App. **3**: 498. 1898. Hairy-panicled panicum.

In dry soil throughout (?).

Herb.: Leiberg 2103, Blue Earth county (?); Aiton, Lake Itasca (?).

Panicum unciphyllum TRIN. Gram. Panic. 242. Hairy panicum.

Panicum pubescens A. GRAY.

Common in dry soil throughout.

Herb.: Numerous specimens.

Panicum leibergii (VASEY) SCRIBN.; Vasey, U. S. Dept. Agric., Div. Bot. Bull. 8: 32. 1889. Leiberg's panicum.

Common in dry soil south.

Herb.: Numerous specimens.

Panicum scribnerianum NASH, Bull. Torr. Club, **22**: 421. 1895. Scribner's panicum.

Panicum pauciflorum A. GRAY, Man. 613. 1848.

Common in dry soil south.

Herb.: Specimens collected throughout southern Minnesota.

Panicum xanthophysum A. GRAY, Ann. Lyc. N. Y. 3: 233. 1835. Slender panicum.

Dry soil throughout.

Herb.: Aiton, Lake Itasca; Sheldon, Mille Lacs Indian Reservation, 2831 Kanabec county; Schuette, St. Anthony Park; Ballard 1419, Cass county.

Panicum porterianum NASH, Bull. Torr. Club, 22: 420. 1895. Broad-leaved panicum.

Panicum latifolium WALT. Fl. Car. 73. 1788.

Common in woods south.

Herb.: Rosendahl 210 and 487, Wheeler 388, Houston county; Oestlund, Sandberg, Aiton, Hennepin county; Ballard 487, Scott county; Taylor 1599, Lindstrom; Hvoslef, Lanesboro.

Chætochloa verticillata (L.) SCRIBN. U. S. Dept. Agric., Div. Agrost. Bull. 4: 39. 1897. Fox-tail grass.

Setaria verticillata BEAUV. Agrost. 51. 1812.

Reported in Upham's catalog but not represented by specimens.

Chætochloa glauca (L.) SCRIBN. U. S. Dept. Agric., Div. Agrost. Bull. 4: 39. 1897. Yellow pigeon-grass.

Setaria glauca BEAUV. Agrost. 51. 1812.

Abundant as a weed throughout.

Herb.: Numerous specimens.

Chætochloa viridis (L.) SCRIBN. U. S. Dept. Agric., Div. Agrost. Bull. 4: 39. 1897. Green pigeon-grass.

Setaria viridis BEAUV. Agrost. 51. 1812.

Abundant as a weed throughout.

Herb.: Numerous specimens.

Chætochloa italica (L.) SCRIBN. U. S. Dept. Agric., Div. Agrost. Bull. 4: 39. 1897. Hungarian millet.

Setaria italica R. & S. Syst. 2: 493. 1817.

Locally escaped from cultivation.

Herb.: Foote, Worthington; Sandberg, Hennepin county.

Cenchrus tribuloides L. Sp. Pl. 1050. 1753. Sand-bur, Bur-grass.

Common in sandy soil throughout.

Herb.: Many specimens.

Zizania aquatica L. Sp. Pl. 991. 1753. Wild rice, Indian rice.

Common in shallow water and swamps throughout.

Herb.: Numerous specimens.

Homalocenchrus virginicus (WILLD.) BRITTON, Trans. N. Y. Acad. Sci. 9: 14. 1889. White grass.

Leersia virginica WILLD. Sp. Pl. 1: 325. 1797.

Infrequent south.

Herb.: Sandberg, Oestlund, Aiton, Hennepin county; Ballard 1172, Zumbrota; Sandberg, Goodhue county; Wheeler 564, Houston county.

Homalocenchrus oryzoides (L.) POLL. Hist. Pl. Palat. 1: 52. 1776. Rice cut-grass.

Leersia oryzoides SW. Fl. Ind. Occ. 1: 132. 1797.

Common throughout in moist places.

Herb.: Numerous specimens.

Homalocenchrus lenticularis (MICHX.) SCRIBN. Mem. Torr. Club, 5: 33. 1894. Catch-fly grass.

Leersia lenticularis MICHX. Fl. Bor. Am. 1: 39. 1803.

Rare southeast.

Herb.: Lyon 713, Houston county.

Phalaris arundinacea L. Sp. Pl. 55. 1753. Reed canary grass.

Common in moist soil throughout.

Herb.: Numerous specimens.

Phalaris canariensis L. Sp. Pl. 54. 1753. Canary grass.

Adventive throughout.

Herb.: Well represented by specimens.

Anthoxanthum odoratum L. Sp. Pl. 28. 1753. Sweet vernal grass.

Adventive southeast.

Herb.: Holzinger 3556, Winona.

Savastana odorata (L.) SCRIBN. Mem. Torr. Club, 5: 34. 1894. Holy grass, Vanilla grass.

Hierochloa borealis R. & S. Syst. 2: 513. 1817.

Hierochloa odorata fragrans (WILLD.) RICHT. Pl. Eur. 1: 31. 1890.

Common throughout the state especially in the northern part. One of our very earliest grasses.

Herb.: Sheldon 175, Blue Earth county, 2062, 2367, Aitkin county; Sandberg, Goodhue and Hennepin counties; Aiton,

Hubbard county; Frost, Minneapolis; Bailey, Vermilion Lake; Sedge, Detroit.

Aristida curtissii (A. GRAY) NASH in Britton, Man. 94. 1901. Curtiss's three-awned grass.

In dry soil. Not previously reported from Minnesota.

Herb.: Upham, Minneapolis, 1884.

Aristida basiramea ENGELM. Vasey, Coult. Bot. Gaz. **9**: 76. 1884. Poverty grass. Three-awned grass.

Frequent in dry soil south.

Herb.: Sandberg, Wollan, Aiton, Hennepin county; Holzinger, Winona county; Sandberg, Crow Wing county; Sheldon 6169, Taylors Falls.

Aristida longiseta robusta MERRILL, U. S. Dept. Agric., Div. Agrost. Cir. 34: 5. 1901. Long-awned aristida.

Aristida purpurea of authors, not NUTT.

Infrequent in dry soil southwest.

Herb.: Leiberg, Rock and Blue Earth counties; Skinner, Heron lake; Sheldon, Lake Benton.

Aristida purpurea NUTT. Trans. Am. Phil. Soc. **5**: 145. 1837.

All reports of this species from Minnesota should be referred to *Aristida longiseta robusta* Merrill.

Aristida purpurascens POIR. in Lam. Encycl. Suppl. **1**: 452. 1810. Purplish aristida.

Reported from Minnesota by Lapham but probably of doubtful occurrence.

Aristida tuberculosa NUTT. Gen. **1**: 57. 1818. Sea-beach aristida.

Reported from Minnesota by Lapham but is not represented by specimen in the University herbarium.

Stipa macouni SCRIBN.; Macoun, Cat. Can. Pl. **5**: 390. 1890. Macoun's stipa.

Reported from north shore of Lake Superior by Macoun. No Minnesota specimens known to have been collected.

Stipa viridula TRIN. Mem. Acad. St. Petersb. (VI.) **2**: 39. 1836. Green stipa.

Rare, west.

Herb.: Skinner 41, Heron lake.

Stipa avenacea L. Sp. Pl. 78. 1753. Black oat-grass.

Reported by E. P. Sheldon in the Minnesota Botanical Studies from Poplar Island lake, Ramsey county. The speci-

men so labelled in the University herbarium is *Stipa comata* Trin. & Rupr. There are no Minnesota specimens of *Stipa avenacea* in the University herbarium.

Stipa comata Trin. & Rupr. Agrost. 3: 75. 1842. Western stipa.

Not previously reported from Minnesota.

Herb.: Sheldon, Poplar Island lake, St. Anthony Park.

Stipa spartea Trin. Mem. Acad. St. Petersb. (VI.) 1: 82. 1831. Porcupine grass, Devil's darning-needle.

Common on dry soil throughout.

Herb.: Numerous specimens.

Oryzopsis canadensis (Poir.) Torr. Fl. N. Y. 2: 433. 1843. Slender mountain rice.

Oryzopsis juncea (Michx.) B.S.P. Prel. Cat. N. Y. 67. 1888.

Common in the vicinity of the headwaters of the Mississippi river and probably extending throughout northern Minnesota.

Herb.: Lyon, Rosendahl, Butters and Wheeler, and Aiton, Lake Itasca; Sheldon 2071 and 2347, Aitkin county, 2012, Brainerd; Anderson 407, Cass county.

Oryzopsis asperifolia Michx. Fl. Bor. Am. 1: 51. 1803. White mountain rice.

Common north of the twin cities, rare south.

Herb.: Sheldon, 4561, Lake county, 2097, Aitkin county, 1926 Hennepin county, 4613 Tower, 6192 Taylors Falls; Ballard, Cass county; Lyon, Rosendahl, Butters and Wheeler, 38, Lake Itasca.

Oryzopsis melanocarpa Muhl. Gram. 79. 1817. Black mountain rice.

In woods throughout?

Herb.: Sandberg, Herrick, Aiton, MacMillan, Hennepin county; Ballard 1794, Cass county; Campbell, St. Cloud; Taylor 949, Glenwood; Sandberg, Isanti county.

Milium effusum L. Sp. Pl. 61. 1753. Tall millet-grass.

Rare in moist woods. Not previously reported from Minnesota.

Herb.: Sheldon 164, Waseca county, 2996, Milaca; Wheeler, Ramsey county.

Muhlenbergia sobolifera (Muhl.) Trin. Unifl. 189. 1824. Rock muhlenbergia.

Reported from Minnesota but not represented by specimens. Probably does not occur here.

Muhlenbergia mexicana (L.) TRIN. Unifl. 189. 1824. Meadow muhlenbergia.

Common throughout.

Herb.: Numerous specimens.

Muhlenbergia racemosa (MICHX.) B.S.P. Prel. Cat. N. Y. 67. 1888. Wild timothy.

Muhlenbergia glomerata TRIN. Unifl. 191. 1824.

Common throughout.

Herb.: Numerous specimens.

Muhlenbergia sylvatica TORR. Fl. U. S. 1: 87. 1824. Wood muhlenbergia.

Rare along eastern border.

Herb.: Sandberg, Hennepin county.

Muhlenbergia ambigua TORR. Nicollet's Rep. 164. 1843. Minnesota muhlenbergia.

Herb.: Type from Lake Okaman in Columbia University. Not examined for this report.

Muhlenbergia tenuiflora (WILLD.) B.S.P. Prel. Cat. N. Y. 67. 1888. Slender muhlenbergia.

Muhlenbergia willdenovii TRIN. Unifl. 188. 1824.

Reported from southern Minnesota in Upham's catalog. No Minnesota specimens in the University herbarium.

Muhlenbergia diffusa SCHREB. Beschr. Gras. 2: 143. *pl. 51.* 1772–1779.

A collection of John Leiberg from Blue Earth county and one by E. P. Sheldon from Otter Tail county, reported in the Metaspermæ of the Minnesota Valley and Minnesota Botanical Studies as *Muhlenbergia diffusa* Shreb., are not this species, but are very slender forms of *Muhlenbergia mexicana* (L.) Trin. There are no authentic collections known from Minnesota.

Brachyelytrum erectum (SCHREB.) BEAUV. Agrost. 39. 1812. Bearded short-husk.

Brachyelytrum aristatum R. &. S. Syst. 2: 413. 1817.

Infrequent in moist places.

Herb.: Sandberg, Aiton, Hennepin county; Ballard 397, Scott county; Bailey 397, Mud Lake; Sandberg, Aitkin county.

Phleum pratense L. Sp. Pl. 59. 1753. Timothy.

Escaped from cultivation throughout.

Herb.: Numerous collections.

Alopecurus geniculatus L. Sp. Pl. 60. 1753. Marsh foxtail.

The flowering glume of this species, with its geniculate awn about twice the length of the glume, clearly distinguishes this from the next, with its straight awn barely equalling the glume in length.

Rare in moist places southwest. All previous reports refer to the following species.

Herb.: Moyer, Montevideo; Lugger, Pipestone.

Alopecurus fulvus SMITH, Engl. Bot. *pl. 1467*. 1793. Marsh foxtail.

Alopecurus geniculatus fulvus SCRIBN. Mem. Torr. Club, 5: 38. 1894.

Alopecurus geniculatus aristulatus TORR. Fl. U. S. **1**: 97. 1824.

Common in wet soil throughout.

Herb.: Well represented by collections from all parts of the state.

Alopecurus pratensis L. Sp. Pl. 60. 1753. Meadow foxtail.

Locally escaped from cultivation.

Herb.: Chapman, Hennepin county.

Sporobolus asper (MICHX.) KUNTH. Enum. **1**: 210. 1833.

Reported from Minnesota in Upham's catalog. Probably does not occur in this state.

Sporobolus vaginæflorus (TORR.) WOOD, Classbook, 775. 1861.

Reported from Minnesota but probably does not occur here. Illinois is given as the northwestern limit in Britton's Manual.

Sporobolus neglectus NASH, Bull. Torr. Club, **22**: 464. 1895. Small rush-grass.

Dry places, rare. Not previously reported from Minnesota.

Herb.: Sheldon 3820, Otter Tail county (?).

Sporobolus brevifolius (NUTT.) SCRIBN. Mem. Torr. Club, **5**: 39. 1895. Short leaved rush-grass.

Sporobolus depauperatus SCRIBN. Bull. Torr. Club, **9**: 103. In part. 1882.

Prairie region, southwest.

Herb.: Sheldon, Brown's Valley, Lake Benton; Menzel, Pipestone.

Sporobolus cuspidatus (TORR.) WOOD, Bot. and Fl. 385. 1870. Prairie rush-grass.

Sporobolus brevifolius SCRIBN. Mem. Torr. Club, **5**: 39. In part. 1895.

Dry soil throughout except northeast.

Herb.: Well represented by collections.

Sporobolus ejuncidus Nash in Britton, Man. 106. 1901. Purple dropseed-grass.

Sporobolus junceus (Michx.) Kunth. Rev. Gram. 1: 68. 1835.

Reported from Wisconsin and Minnesota by Lapham. This report is probably incorrect, as neither of these comes within the known range of the species.

Sporobolus cryptandrus (Torr.) A. Gray, Man. 576. 1848. Sand dropseed-grass.

In sandy soil throughout.

Herb.: Sheldon, Oestlund, Aiton, Hennepin county; Sheldon 3435 and 3362, Otter Tail county; Campbell, Stearns county.

Sporobolus heterolepis A. Gray, Man. 576. 1848. Strong-scented dropseed.

In dry soil throughout.

Herb.: Collections from Hennepin, Otter Tail, Lincoln, Goodhue, Traverse, Winona and Blue Earth counties.

Cinna arundinacea L. Sp. Pl. 5. 1753. Indian reed.

Swamps, infrequent.

Herb.: Sandberg, Isanti county; Ballard 1173, Zumbrota.

Cinna latifolia (Trev.) Griseb. in Ledeb. Fl. Ross. 4: 435. 1853. Slender Indian reed.

Cinna pendula Trin. Mem. Acad. St. Petersb. (VI.) 6: 280. 1841.

In moist soil north.

Herb.: Bailey 323, St. Louis river; MacMillan & Sheldon 85, Brainerd; Sandberg, Hennepin county.

Agrostis alba L. Sp. Pl. 63. 1753. Red-top.

Agrostis vulgaris With. Bot. Arr. Brit. Pl. Ed. 3, 132. 1796.

Agrostis alba vulgaris Thurber in A. Gray, Man. Ed. 6, 647. 1890.

Escaped from cultivation throughout Minnesota.

Herb.: Numerous specimens.

Agrostis canina L. Sp. Pl. 62. 1753.

Reported from Pipestone county in Upham's catalog. Of doubtful occurrence in the state.

Agrostis perennans (WALT.) TUCKERM. Am. Journ. Sci. **45**: 44. 1843. Thin grass.

Rare in moist places.

Herb.: Sandberg, Isanti and Hennepin counties.

Agrostis hyemalis (WALT.) B.S.P. Prel. Cat. N. Y. 68. 1888. Tickle-grass, Rough hair-grass.

Agrostis scabra WILLD. Sp. Pl. **1**: 370. 1798.

Common throughout.

Herb.: Very numerous collections.

Calamagrostis breviseta lacustris KEARNEY, U. S. Dept. Agric., Div. Agrost. Bull. **11**: 25. 1898. Reed-grass.

C. Lapponica A. GRAY, Proc. Am. Acad. **6**: 78. 1862. In part.

Along north shore of Lake Superior.

Herb.: F. F. Wood, St. Louis and Cook counties. Both specimens in the U. S. Nat. Herbarium.

Calamagrostis langsdorfi (LINK) TRIN. Unifl. 225. *pl. 4. f. 10.* 1824. Reed-grass, Blue-joint.

Near Lake Superior.

Herb.: T. S. Roberts, Bailey 519, Agate Bay.

Calamagrostis canadensis (MICHX.) BEAUV. Agrost. 157. 1812. Blue-joint, Reed grass.

Deyeuxia canadensis MUNRO; Hook. f., Trans. Linn. Soc. **23**: 345.

Moist soil throughout, common.

Herb.: Many collections.

Calamagrostis macouniana VASEY, Monog. Grasses U. S., Contr. U. S. Nat. Herb. **3**: 81. 1892. Macoun's reed-grass.

Rare northwest.

Herb.: Ballard, Cass county.

Calamagrostis neglecta (EHRH.) GAERTN.; Gaertn., Mey., und Scherb. Fl. Wetteran, **1**: 94. 1799. Narrow reed-grass.

Deyeuxia neglecta KUNTH. Enum. **1**: 76. 1833.

In moist soil throughout.

Herb.: Ballard 925 and 1032, Nicollet county: Sheldon 331 and 481, Blue Earth county.

Calamagrostis inexpansa A. GRAY, Gram. et Cyp. 1: No. 20. 1834. Bog reed-grass.

Calamagrostis confinis A. GRAY, Man. Ed. 2: 547. 1856. Not Nutt.

Herb.: Sandberg, no locality, 1891 (collection reported by Kearney); Ballard, Nicollet county?

Calamagrostis hyperborea elongata Kearney, U. S. Dept. Agric., Div. Agrost. Bull. 11: 40. 1898. Northern reed grass.

In moist soil throughout.

Herb.: Sheldon 3615, 3788, Otter Tail county; Foote, Jarvis, Ramsey county; Ballard 582, Scott county; Campbell, St. Cloud.

Calamagrostis cinnoides (MUHL.) BART. Comp. Fl. Phila. 1: 45. 1818.

Calamagrostis nuttalliana STEUD. Syn. Pl. Gram. 190. 1855.

Reported from Minnesota but probably does not occur here.

Ammophila arenaria (L.) LINK, Hort. Berol. 1: 105. 1827. Sea sand-weed.

Ammophila arundinacea HOST, Gram. Austr. 4: 24. 1809.

Reported as occurring along the south shore of Lake Superior and probably along the north shore. There are no specimens from Minnesota to verify this report.

Calamovilfa longifolia (HOOK.) HACK. True Grasses, 113. 1890. Long-leaved reed-grass.

Calamagrostis longifolia HOOK. Fl. Bor Am. 2: 241. 1840.

Common on sandy soil throughout.

Herb.: Many collections.

Deschampsia cæspitosa (L.) BEAUV. Agrost. 160. *pl. 18. f. 3.* 1812. Tufted hair-grass.

Northern part of state, frequent.

Herb.: Sandberg, Thomson; Wood, Grand Marais; Cheney 22, Hunter's Island; Bailey 424, Vermilion lake.

Trisetum subspicatum (L.) BEAUV. Agrost. False oats.

On rocks, north shore of Lake Superior.

Herb.: Bailey 490, Agate bay; Wood, Grand Marais; Sandberg, Two Harbors.

Avena striata Michx. Fl. Bor. Am. **1**: 73. 1803. Purple oats.

Frequent in woods north.

Herb.: Ballard 1230, Anderson, 406, Cass county; Sandberg, Washington county; Aiton, Lake Itasca; Sheldon 2736, Milaca; Sandberg 101, N. P. Junction.

Avena fatua L. Sp. Pl. 80. 1753. Wild oats.

Common in cultivated and waste ground throughout. Much more widely distributed than the number of herbarium specimens would indicate.

Herb.: Moyer, Chippewa county; Ballard, 836, Waconia.

Arrhenatherum elatius (L.) Beauv.; M. & R. Deutsch. Fl. **1**: 546. 1823. Oat-grass.

Adventive near the Twin Cities and perhaps elsewhere in the state.

Herb.: Sandsten, Ramsey county.

Danthonia spicata (L.) Beauv.; R. & S. Syst. **2**: 690. 1817. Wild oat-grass.

Common throughout in dry soil.

Herb.: Ballard, Nicollet and Cass counties; Sandberg, Carlton and Douglas counties; Aiton, Lake Itasca; Wood, no locality; Sheldon 2833, Kanabec county; Rosendahl 514, Spring Grove.

Spartina cynosuroides (L.) Willd. Enum. 80. 1809. Tall marsh-grass, Fresh-water cord-grass.

Common in wet places throughout.

Herb.: Numerous collections.

Spartina gracilis Trin. Agrost. **1**: 88. 1840. Inland cord-grass.

Rare in alkaline soil southwest.

Herb.: Menzel, Pipestone, Aug., 1894.

Schedonnardus paniculatus (Nutt.) Trelease, Branner & Coville, Rep. Geol. Surv. Ark. **1888**: Part 4, 236. 1891. Schedonnardus.

Rare southwest.

Herb.: Menzel, Pipestone, July, 1895.

Bouteloua hirsuta Lag. Var. Cienc. y Litter. **2**: Part 4, 141. 1805. Hairy mesquite-grass.

Common in dry soil throughout.

Herb.: Numerous specimens.

Bouteloua oligostachya (NUTT.) TORR.; A. Gray, Man. Ed. 2, 553. 1856. Mesquite-grass, Grama-grass.

Dry soil throughout; common west.

Herb.: Collections not so numerous as those of *Bouteloua hirsuta* Lag.

Atheropogon curtipendulus (MICHX.) FOURN. Mex. Pl. En. Gram. 138. Racemed grama-grass.

Bouteloua curtipendula (MICHX.) TORR. Emory's Rep. 153. 1848.

Bouteloua racemosa LAG. Var. Cienc. y Litter. 2: Part 4, 141. 1805.

Common in dry soil throughout.

Herb.: Numerous collections.

Beckmannia erucæformis (L.) HOST, Gram. Austr. 3: 5: 1805. Beckmannia.

Common throughout the prairie region.

Herb.: Numerous collections from western Minnesota.

Bulbilis dactyloides (NUTT.) RAF.; Kuntze, Rev. Gen. Pl. 763. 1891. Buffalo grass.

Buchloe dactyloides ENGELM. Trans. St. Louis Acad. 1: 432. 1859.

Rare on dry prairies southwest.

Herb.: Leiberg 94, Pipestone quarry.

Phragmites phragmites (L.) KARST. Deutsch. Fl. 379. 1880–1883. Corn grass, Reed.

Phragmites communis TRIN. Fund. Agrost. 134. 1820.

Common in wet soil throughout.

Herb.: MacMillan and Skinner 394, Crookston; MacMillan and Sheldon 3, Brainerd; Sandberg, Hennepin county; Taylor 222, Janesville, 1019, Glenwood; Wheeler 1142, Luverne.

Eragrostis capillaris (L.) NEES, Agrost. Bras. 505. 1829. Capillary eragrostis.

Reported from Minnesota by Upham but probably does not occur in our range.

Eragrostis frankii STEUD. Syn. Pl. Gram. 273. 1855. Frank's eragrostis.

Reported from Minnesota. There are no specimens in the University herbarium to verify the report.

Eragrostis pilosa (L.) BEAUV. Agrost. 162. 1812. Tufted eragrostis.

The report of this species from Minnesota may be correct but there are no specimens known to verify it.

Eragrostis purshii SCHRAD. Linnæa, **12**: 451. 1838. Pursh's eragrostis.

Common in dry soil throughout.

Herb.: Numerous collections.

Eragrostis major HOST, Gram. Austr. **4**: 14. *pl. 24.* 1809. Strong-scented eragrostis.

Eragrostis poæoides megastachya A. Gray, Man. Ed. 5, 631. 1867.

Waste and cultivated ground throughout.

Herb.: Numerous specimens.

Eragrostis pectinacea (MICHX.) STEUD. Syn. Pl. Gram. 272. 1855. Purple eragrostis.

In dry soil south.

Herb.: Sandberg, Oestlund, Sheldon, Aiton, Hennepin county; Ballard 638, Chaska; Sandberg, Redwing.

Eragrostis refracta (MUHL.) SCRIBN. Mem. Torr. Club, **5**: 49. 1894. Meadow eragrostis.

Eragrostis campestris TRIN. Bull. Acad. Sci. St. Petersb. **1**: 70. 1836.

Reported in Minnesota Botanical Studies, **1**: 67, 1894, as adventive at St. Anthony Park. There are no specimens in the University herbarium.

Eragrostis hypnoides (LAM.) B.S.P. Prel. Cat. N. Y. 69. 1888. Creeping eragrostis.

Eragrostis reptans NEES, Agrost. Bras. 514. 1829.

River and lake shores throughout.

Herb.: Numerous specimens.

Eatonia obtusata (MICHX.) A. GRAY, Man. Ed. 2, 558. 1856. Blunt-scaled eatonia.

In dry soil throughout. Very often confused with *Koeleria cristata* (L.) Pers. by collectors.

Herb.: Numerous collections.

Eatonia pennsylvanica (DC.) A. GRAY, Man. Ed. 2, 558. 1856. Pennsylvania eatonia.

Infrequent throughout.

Herb.: Rosendahl 534, Spring Grove; Ballard 325, Belle Plain; Taylor 658, Blue Earth county; Bailey, 32, Vermilion Lake.

Koeleria cristata (L.) PERS. Syn. **1**: 97. 1805. Koeleria.

One of the most common grasses, in dry soil throughout.

Herb.: Numerous collections.

Melica diffusa PURSH, Fl. Am. Sept. 77. 1814. Tall melic grass.

Rare southeast. Not previously reported from Minnesota.

Herb.: Rosendahl, Spring Grove.

Melica mutica WALT. Fl. Car. 78. 1788. Narrow melic grass.

Rare southeast. Collected by L. H. Pammel in Houston county in 1898. This is the only collection known from this state.

Korycarpus diandrus (MICHX.) KUNTZE, Rev. Gen. Pl. 772. 1891. American korycarpus.

Diarrhena americana BEAUV. Agrost. 142. 1812.

Reported from Sherburne county but probably does not extend so far north as Minnesota.

Distichlis spicata (L.) GREENE, Bull. Cal. Acad. **2**: 415. 1887. Marsh spike-grass.

A collection by Professor MacMillan from Renville county is reported in the Minnesota Botanical Studies, **1**: 68, 1894. There is no specimen from this collection in the University herbarium.

Dactylis glomerata L. Sp. Pl. 71. 1753. Orchard grass.

Escaped from cultivation throughout.

Herb.: Skinner, Heron lake; Wheeler 1253, St. Anthony Park; Aiton, Hennepin county; C. A. Sylvester, Madelia.

Poa annua L. Sp. Pl. 68. 1753. Annual meadow-grass.

Waste places probably throughout.

Herb.: Kassube 191, Minneapolis.

Poa nemoralis L. Sp. Pl. 69. 1753. Wood meadow-grass.

Poa cæsia strictior A. GRAY, Man. Ed. 5, 629. 1867.

Throughout. Often confused with *Poa flava* L. by collectors.

Herb.: Sandberg, Red Wing; Sheldon 2501, Mille Lacs Indian Reservation,

Poa flava L. Sp. Pl. 68. 1753. False redtop, Fowl meadow-grass.

Poa serotina EHRB. Beitr. 6: 83. 1791.

Poa palustris L. Syst. 874. 1759.

Common throughout.

Herb.: Specimens from thirty-four collections in the University herbarium, many of which have been previously determined and reported by the collectors as *Agrostis alba* L.

Poa pratensis L. Sp. Pl. 67. 1753. Kentucky blue-grass, June grass.

Abundant throughout.

Herb.: Numerous specimens.

Poa glauca VAHL, Fl. Dan. *pl. 964*. 1790. Glaucous spear-grass.

Poa cæsia J. E. SMITH, Eng. Bot. *pl. 1719*. 1807.

Reported by Upham but probably does not occur in Minnesota.

Poa debilis TORR. Fl. N. Y. 2: 459. 1843. Weak spear-grass.

In woods, north.

Herb.: Aiton, Lake Itasca; Sheldon 2608, Mille Lacs Reservation.

Poa sylvestris A. GRAY, Man. 596. 1848. Sylvan spear-grass.

Reported by Upham but probably does not reach so far north as Minnesota.

Poa alsodes A. GRAY, Man. Ed. 2, 562. 1856. Grove meadow-grass.

Rare east.

Herb.: Sandberg, Thomson.

Poa wolfii SCRIBN. Bull. Torr. Club, 21: 228. 1894. Wolf's meadow-grass.

Rare southeast. Not previously reported from Minnesota.

Herb.: Rosendahl 285, Spring Grove.

Poa pseudopratensis SCRIBN. & RYDB. in Br. & Br. Illus. Fl. 1: 204. 1896. Prairie meadow-grass.

Western prairies.

Herb.: Moyer, Montevideo. (Determined at the U. S. Dept. of Agric.)

Poa alpina L. Sp. Pl. 67. 1753. Alpine spear-grass.
North shore of Lake Superior.
Herb.: Sandberg, Two Harbors?

Poa compressa L. Sp. Pl. 69. 1753. Flat-stemmed meadow-grass.
Waste and cultivated grounds throughout.
Herb.: Many specimens.

Scolochloa festucacea (WILLD.) LINK, Hort. Berol. 1: 137. 1827. Fescue scolochloa.

No previous report based on authentic Minnesota collection. The report in Upham's catalog is based entirely on Cratty's Iowa collection.

Herb.: Sheldon 448, Blue Earth county; Ballard 937, Nicollet county; MacMillan and Sheldon 1452, Sandy Beach.

Graphephorum melicoideum (MICHX.) BEAUV. Agrost. 164. *pl. 15. f. 8.* 1812. Graphephorum.

No authentic collection known from Minnesota.

MacMillan and Sheldon's collection number 1452 from Sandy Beach, Lake of the Woods, reported in the Minnesota Botanical Studies, 1: 964 and 975, as this species is *Scolochloa festucacea* (Willd.) Link.

Panicularia canadensis (MICHX.) KUNTZE, Rev. Gen. Pl. 783. 1891. Rattle-snake grass.
Glyceria canadensis TRIN. Mem. Acad. St. Petersb. (VI.) 1: 366. 1831.
Common in wet places north, less frequent south.
Herb.: Many collections.

Panicularia torreyana (SPRENG.) MERRILL, Rhodora, 4: 146. 1902.
Glyceria elongata TRIN. Gram. Suppl. 58: 1836.

The report in Upham's catalog on this species is doubtful. There are no known specimens from Minnesota.

Panicularia nervata (WILLD.) KUNTZE, Rev. Gen. Pl. 783. 1891. Nerved manna-grass.
Glyceria nervata TRIN. Mem. Acad. St. Petersb. (VI.) 1: 365. 1831.
In wet places throughout.
Herb.: Numerous specimens.

Panicularia americana (TORR.) MACM. Met. Minn. Val. 81. 1892. Reed meadow-grass.

Glyceria grandis S. WATS. in A. Gray, Man. Ed. 6: 667. 1890.

Wet places throughout.

Herb.: Numerous collections.

Panicularia fluitans (L.) KUNTZE, Rev. Gen. Pl. 782. 1891. Floating manna-grass.

Glyceria fluitans R. BR. Prodr. Fl. Nov. Holl. 1: 179. 1810.

No authentic specimens known from Minnesota.

All collections from Minnesota in the University herbarium under this name are *Panicularia borealis* Nash.

Panicularia borealis NASH, Bull. Torr. Club, 24: 348. 1897. Slender manna-grass.

Glyceria fluitans minor VASEY; L. S. Cheney in Trans. Wis. Acad. Sci. 9: 247. No description.

In wet places throughout.

Herb.: Many collections.

Puccinellia airoides (NUTT.) WATS. & COULT. in A. Gray, Man. Ed. 6, 668. 1890. Slender meadow-grass.

Saline soil, Red River valley.

Herb.: Ballard 2528, Fergus Falls; MacMillan and Sheldon, Lake of the Woods.

Festuca octoflora WALT. Fl. Car. 81. 1788. Slender fescue-grass.

Festuca tenella WILLD. Enum. 1: 113. 1809.

Dry sandy soil throughout.

Herb.: Many collections from southern half of state.

Festuca rubra L. Sp. Pl. 74. 1753. Red fescue-grass.

Reported from Minnesota and possibly occurs along the northern boundary.

Festuca ovina L. Sp. Pl. 73. 1753. Sheep fescue-grass.

Probably occurs throughout the state.

Herb.: Sandberg, Thomson; Bailey 489, Agate bay; Campbell, St. Cloud; Bailey 450, Vermilion lake; Sheldon 2669, Aitkin county; Sandsten, Ramsey county; Chapman, Hennepin county.

Festuca elatior L. Sp. Pl. 75. 1753. Meadow fescue-grass.

Fields and cultivated grounds throughout.

Herb.: Rosendahl, Spring Grove; Wheeler, Hennepin county; Skinner, Heron lake.

Festuca shortii KUNTH.; Wood, Class-book, 794. 1861. Short's fescue-grass.

Rare southeast, not previously reported from Minnesota.

Herb.: Sandberg 43, Goodhue county.

Festuca nutans WILLD. Enum. 1: 116. 1809. Nodding fescue-grass.

In woods throughout.

Herb.: Many collections.

Bromus inermis LEYSS. Fl. Ital. 16. 1761. Hungarian brome-grass.

Recently introduced into the state as a forage plant and has escaped from cultivation in some places.

Bromus ciliatus L. Sp. Pl. 76. 1753. Fringed brome-grass.

In woods throughout.

Herb.: Numerous collections.

Bromus purgans L. Sp. Pl. 176. 1753. Wood chess.

In woods throughout.

Herb.: Numerous collections.

Bromus purgans latiglumis (SCRIBN.) SHEAR, U. S. Dept. Agric., Div. Agrost. Bull. 23: 40. 1900. Broad-glumed wood chess.

With the species.

Herb.: Ballard 1161, Goodhue county. (Determined by C. L. Shear.)

Bromus kalmii A. GRAY, Man. 600. 1848. Hairy chess.

Common throughout.

Herb.: Numerous collections.

Bromus secalinus L. Sp. Pl. 76. 1753. Chess, Cheat.

Fields and waste places. A common weed in grain fields south.

Herb.: Lyon 184, Houston county; Frost 218, Willmar; Holzinger 44, Winona; Ballard 221, Scott county; Sheldon 661, Waseca.

Bromus racemosus L. Sp. Pl. Ed. 2, 114. 1762. Upright chess.

Previously reported by Upham and may occur here. It may however have been confused with *Bromus secalinus* L., from which it is with difficulty distinguished.

Lolium temulentum L. Sp. Pl. 83. 1753. Darnel.

Locally adventive.

Herb.: Leiberg, Mankato, 1883.

Agropyron richardsoni SCHRAD. in Linnæa, **12**: 467. 1838. Awned wheat-grass.

Agropyron caninum violascens RAMALEY, Minn. Bot. Stud. **1**: 107. 1894.

Agropyron violaceum caninoides RAMALEY, Minn. Bot. Stud. **1**: 107. 1894.

Most collectors have probably confused this with *Agropyron caninum* (L.) R. & S.

Herb.: Campbell 77, St. Cloud; Sheldon 3298, Mille Lacs county; MacMillan and Sheldon 84, Brainerd; Ballard 1726, Cass county; Skinner 203, Heron lake; Wheeler 1223, Ramsey county.

Agropyron caninum (L.) R. & S. Syst. **2**: 756. 1817. Nodding wheat-grass.

Frequently reported from Minnesota. No collections from this state in the University herbarium.

Agropyron tenerum VASEY, Coult. Bot. Gaz. **10**: 258. 1885. Slender wheat-grass.

Common throughout.

Herb.: Ballard 2569, St. Vincent; MacMillan and Skinner 304, 335, Crookston; Sheldon 979, Sleepy Eye, 3299 Mille Lacs county; MacMillan and Sheldon 82, Brainerd; Wheeler, St. Anthony Park.

Agropyron violaceum (HORNEM.) VASEY, Spec. Rep. U. S. Dept. Agric. 63: 45. 1883. Purplish wheat-grass.

Rare north.

Herb.: Bailey 494, Agate Bay.

Agropyron occidentale SCRIBN. U. S. Dept. Agric., Div. Agrost. Cir. 27: 9. 1900. Western quack-grass.

Agropyron repens glaucum (DESF.) SCRIB. Mem. Torr. Club, **5**: 57. 1894.

Agropyron spicatum SCRIBN. and SM. U. S. Dept. Agric., Div. Agrost. Bull. 4: 33. 1897.

Fields and waste places throughout. The most common quack or couch-grass in the state.

Herb.: Numerous specimens.

Agropyron dasystachyum (Hook.) Vasey, Spec. Rep. U. S. Dept. Agric. 63: 45. 1883. Hairy-glumed wheat-grass.

Reported from Minnesota. No authentic collections known.

Agropyron pseudorepens Scribn. and Sm. U. S. Dept. Agric., Div. Agrost. Bull. 4: 34. 1897. False quack-grass.

Throughout.

Herb.: Rosendahl 628, Spring Grove; Moyer, Montevideo; Sheldon 2505, Mille Lacs Reservation; Bailey 511, Agate Bay; Skinner 105, Heron lake.

Agropyron repens (L.) Beauv. Agrost. 146. 1812. Quack-grass.

Commonly adventive east.

Herb.: Rosendahl 446, Spring Grove; Sheldon 2837, Kanabec county; Ramaley 217, Ramsey county; Sandberg 37, Hennepin county; Bailey 42, Vermilion lake.

Hordeum nodosum L. Sp. Pl. Ed. 2, 126. 1762. Meadow barley.

All reports of this species probably refer to the next.

Hordeum pusillum Nutt. Gen. 1: 87. 1818. Little barley.

Dry soil south.

Herb.: Menzel, Pipestone.

Hordeum jubatum L. Sp. Pl. 85. 1753. Squirrel-tail grass.

Common in dry soil throughout.

Herb.: Numerous collections.

Sitanion elymoides Raf. Journ. Phys. 89: 103. 1819. Long-bristled wild rye.

Elymus sitanion Schultes, Mant. 2: 426. 1824.

Reported from southwestern Minnesota. No specimens known to verify report.

Elymus striatus Willd. Sp. Pl. 1: 470. 1797. Slender wild rye.

Common throughout.

Herb.: Wheeler 1067, Luverne; Aiton, Hennepin county; Ballard 1005, Nicollet county; Campbell 129, Stearns county.

Elymus arkansanus Scribn. & Ball, U. S. Dept. Agric., Div. Agrost. Bull. 24: 45. 1900. Arkansas wild rye.

Dry soil south. Previously confused with *Elymus striatus.* Willd.

Herb.: Sheldon 842, 976½. Sleepy eye.

Elymus virginicus L. Sp. Pl. 84. 1753. Stout wild rye.

Common throughout.

Herb.: Aiton, Hennepin county; Wheeler 418, Houston county; Sandberg, Red Wing; Ballard 2629, St. Vincent; Sheldon 3690, Fergus Falls; Oestlund, Minneapolis; MacMillan and Skinner 235, Crookston.

Elymus virginicus minor VASEY, Contrib. U. S. Nat. Herb. 2: 550. May, 1894.

Elymus virginicus jejunus RAMALEY, Minn. Bot. Stud. 1: 114. June, 1894.

Herb.: Sheldon 1375, Lake Benton (Ramaley's type); Bailey 265, St. Louis river.

Elymus diversiglumis SCRIBN. & BALL, U. S. Dept. Agric., Div. Agrost. Bull. 24: 48. 1900.

Probably throughout. Not previously reported from Minnesota.

Herb.: Ballard, Scott county; Anderson, Cass county; MacMillan and Skinner 107, 267, Crookston; Campbell 130, Rockville; Wheeler Wyoming, 1224, St. Anthony Park.

Elymus canadensis L. Sp. Pl. 83. 1753. Nodding wild rye.

Common throughout.

Herb.: Numerous collections.

Elymus crescendus (RAMALEY) n. comb. Robust nodding wild rye.

Elymus canadensis L. forma *crescendus* Ramaley, Minn. Bot. Studies 1: 114. 1894.

Elymus robustus SCRIBN. and SM. U. S. Dept. Agric., Div. Agrost. Bull. 4: 37. 1897.

Common throughout.

Herb.: Sheldon 1120, Springfield (type); Sandberg, Aiton, Anderson, Hennepin county; MacMillan and Sheldon 1120, Oak Point; Sandsten, Ramsey county; Menzel, Pipestone.

Elymus brachystachys SCRIBN. & BALL, U. S. Dept. Agric., Div. Agrost. Bull. 24: 47. 1900. Nodding wild rye.

Rare south.

Herb.: Lewis Foote, Worthington ?

Elymus glaucus BUCKL. Proc. Acad. Phila. 1862: 99. 1862. Smooth wild rye.

Elymus sibiricus L. Sp. Pl. 83. 1753. In part.

Reported in Upham's catalog. No authentic collections known from this state.

Elymus macouni Vasey, Bull. Torr. Club, **13**: 119. 1886. Macoun's wild rye.

Infrequent in dry soil throughout.

Herb.: Ballard 2570, St. Vincent; Skinner 223, Heron lake; Wheeler 1254, St. Anthony Park.

Elymus arenarius L. Sp. Pl. 83. 1753. Downy wild rye.

Reported from the north shore of Lake Superior. No authentic collection known from Minnesota.

Hystrix hystrix (L.) Millsp. Fl. W. Va. 474. 1892. Bottle-brush grass.

Asprella hystrix Willd. Enum. 132. 1809.

Common in woods throughout.

Herb.: Numerous collections.